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VOLUME I JANUARY, 1915 Nos. 3 and 4

SOME DIFFICULTIES IN THE IMPROVEMENT OF INDIAN SUGARCANES.

BY C. A. BARBER, D.Sc.

(*Imperial Department of Agriculture for India.*)

(Plates XIII—XVI and 3 Text-figures.)

THE need for improving the class of sugarcanes grown in India has long been recognised, and fitful efforts in this direction have been made during the last hundred years or more. These efforts have, almost uniformly, resulted in failure, chiefly owing to a lack of appreciation of the factors involved. The subject has, however, again forced itself on the attention of Government because of the steadily increasing imports into India of Java sugar. There is, in India, a much larger acreage under sugarcane than in any other country and it has been not unreasonably maintained that there must be something wrong if it cannot supply its own demand for sugar. The produce of the fields is, however, so low that it is quite insufficient to meet the demands of the growing population.

In approaching the problem anew, it has been considered advisable to make a closer study of the canes themselves and the conditions of soil and climate under which they grow than appears to have been done before, and certain intrinsic difficulties have been met with which may very easily account for former failures. Before considering these it will be well to indicate briefly the conditions referred to. For the sake of conciseness, it is convenient to divide the Indian sugarcane area into two parts, a northern and a southern, as indicated in the accompanying sketch-map. The southern portion, consisting of parts of Madras, Mysore and Bombay, is on the whole well suited for sugarcane growing. It is wholly within the tropics, the temperature is uniformly high throughout the year and, in many places, the soil is good. The rainfall is, however, of such a nature that irrigation is needed to supplement it. India is not blessed with the well-distributed rainfall of tropical islands

and, almost everywhere, there are long periods of drought, often extending for four or five months at a time. Where temperature and soil are suitable, moistness is found to be a limiting factor. In the north, the

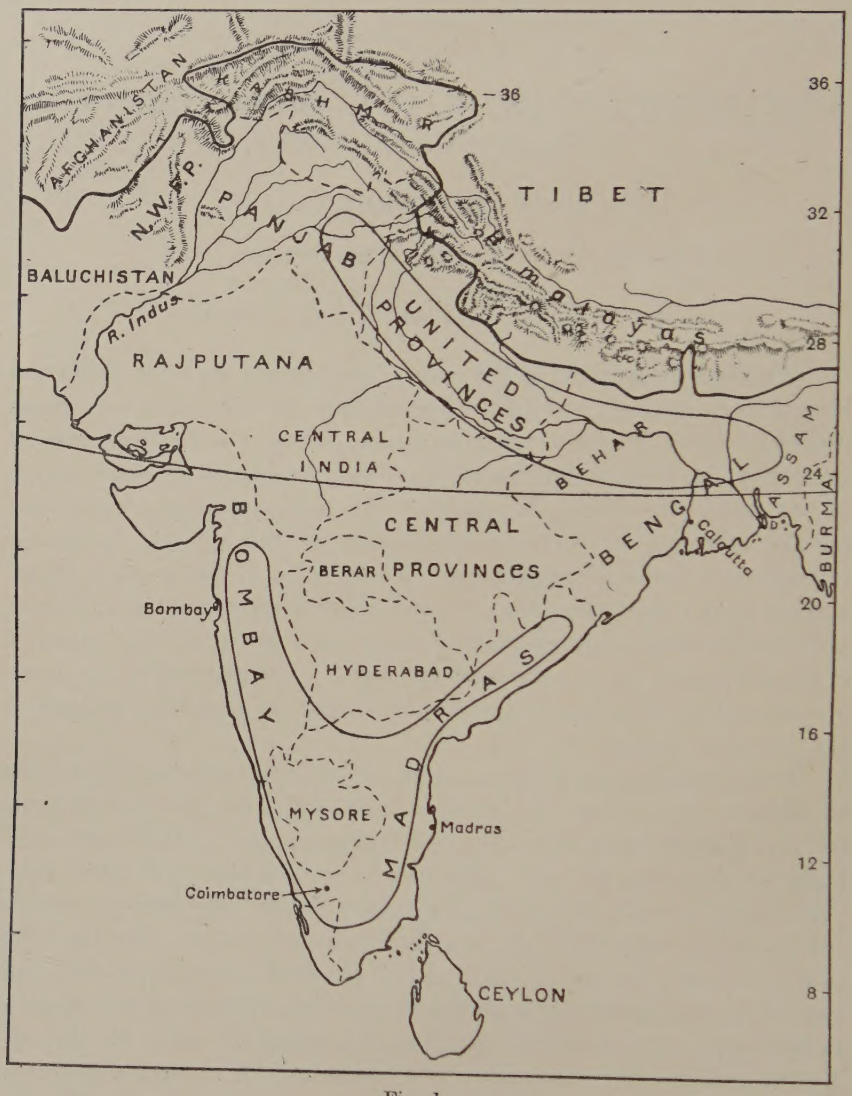

Fig. 1.

main sugarcane tract extends from Assam to the Panjab, along the foot of the Himalayas, a distance of over 1000 miles. On comparing the acreage of these northern and southern regions, it is found that the

cane is much more thickly planted in the former, so that vastly the greater part of the crop is grown in this northern region, constituting an aggregate of something like 4000 square miles. This is entirely outside the tropics. Moisture is adequate, by rain near the hills and a complete network of canals farther south where, however, paddy is no longer a serious rival. The soil is easily permeable, deep and rich, but the total amount of warmth and especially the length of the growing period are insufficient. The continuance of suitable high temperature is the limiting factor here.

This difference in climate between the northern or continental portion and the southern or peninsular has a marked influence on the character of canes grown in the two regions. While the field canes in Southern India are often comparable with those of tropical islands in thickness and vigour, those of North India are much thinner, more fibrous and much less productive of sugar in the crop. The canefields look very different in the two tracts, as may be gathered from the photographs, those in Bengal standing intermediate between the extremes of Madras and the Panjab. And, when the canes are carefully examined, they are generally so unlike in morphological characters and habit that it is worth while considering whether they have been derived from the same ancestral species of Saccharum. These differences in climate and character of the canes have a pronounced effect upon the whole course of cultivation in the field and, while the cultivation of sugarcane in the south is intensive and costly, the crop in the Gangetic plain has little attention paid to it.

Judging by the periodic returns issued by Government, the area under sugarcane remains more or less stationary, but, on the other hand, the population is rapidly increasing. It is still doubtful whether the diminution in poppy-growing will bring much more land under sugarcane, and although there are indications of extension in some localities, there is no immediate prospect of any great increase in the area under this crop. Improvement in production must therefore take the line of increasing the yield per acre. With this object in view, a small department has recently been opened by the Indian Government for the general study of the sugarcanes of the country. There are, of course, various ways in which the problem may be approached. Leaving aside the whole question of improvement in agricultural practice, which is now receiving a good deal of attention, the canes are seen to be obviously inferior in character in North India, and it is natural to consider whether success may not be obtained most rapidly and

economically by replacing them with better kinds. There are four ways in which this may be attempted:—

(1) *The introduction of exotic canes which have proved of value elsewhere.* This method has been the main line followed for many years all over India, from Madras to Peshawar. Thick, tropical canes, the relics of successive importations, are everywhere met with. But it is generally found that these thick canes have not time to mature in the north during the short, hot, moist period. They sometimes grow surprisingly well and are full of juice, but the ripening process by which the glucose is changed to crystallisable sucrose is arrested and, although extensively used as fruit and eaten raw, these thick exotic canes are generally useless for the manufacture of sugar. It is possible that certain early maturing varieties may still be met with, or that changes in treatment may lead to improvement along this line, and this is not being lost sight of, but we have the advantage of actual demonstration of their behaviour all over the country and the prospect of success is not encouraging.

(2) *The transfer of canes from one part of India to another.* This method of improvement is well known to the cultivator. He is not only accustomed to the trial of new varieties valued elsewhere, but is acquainted with the advantage of occasional change of seed in the same variety. Exchanges of varieties are being actively carried on by the Agricultural departments of the various Provinces and occasional advantage accrues from this. Collections of different varieties of sugarcane growing together are a constant feature on local farms. The fine new canes introduced into Madras through the Samalkota farm are now to be met with in every part of India, even extending to the North-West Frontier Province. But success along this line is limited and, in the main, the introduced kinds cannot hold their own against the best local kinds, the latter themselves being the outcome of centuries of selection by the cultivators.

(3) *The improvement of local canes by selection and the observation of sports.* This method has perhaps hardly received the attention during recent years that it undoubtedly deserves, but there are special difficulties in the way with a crop that can only be finally judged after it has passed through the mill and been chemically analysed. The sugarcane has, from time immemorial, been propagated by cuttings, and it is difficult to determine whether chance variations in growth are or are not due to better local treatment or feeding.

(4) *The production of seedlings.* This has been tried many times

in India, but in the past always unsuccessfully. The experiments have not always been conducted very carefully, and on the founding of the new department it was decided to examine the matter afresh and try to determine the cause of failure in the face of the successful results obtained in Java, the West Indies and elsewhere. The solution of the problem turned out to be remarkably simple. Almost all the experiments were made in North India and it transpires that the stamens do not mature and pollen is not formed in the cane flowers there. A cursory glance showed that this was not the case in South India, and in the Government farm opened at Coimbatore in the Madras Presidency some 40,000 seedlings have been raised during the past two years.

Problem 1. During the short time that the cane-breeding station has been in existence, a very important step in advance has been taken and the first problem, that of obtaining seedlings, has been solved. But in considering the ultimate aim of the station more carefully, a number of difficulties have cropped up and it is the intention in the present paper to detail some of these further problems, in the hope that help may be available from the great body of readers interested in plant-breeding.

Problem 2. Most, if not all, of the difficulties in procuring suitable cane seedlings have arisen from the fact that the flowering is irregular—in fact, comparatively rare. If a cane flowers and we obtain seedlings from it, we cannot count on these seedlings flowering. We have no means at present of inducing the canes we are most interested in to flower. Control of the flowering is the second difficulty we have encountered.

Arrowing of the cane, as the production of the inflorescence is called, is comparatively rare in North India, but occasionally it occurs over large areas. It is viewed with alarm in certain regions, and there appears to be some reason for connecting it with the weather and especially with a failure of the normal rains. Flowering of the sugarcane appears to be commoner in years of drought, but details on this point are not yet available. In Mysore and Coimbatore, typically dry tracts, flowering is common, and on the other Madras farms where sugarcane is grown, in Malabar, Godavari and South Arcot, the amount of flowering seems to vary inversely with the moistness of the climate. On the other hand, it is a common belief among Coimbatore cultivators that arrowing is most frequent in water-logged conditions of the roots. Experiments are now being conducted on the farm with different soils and different amounts of moisture to see if any effect is produced,

for it is felt that, until some control of flowering is obtained, working along Mendelian lines is more or less out of the question. If the supposition of the Coimbatore ryots is correct, it would seem to indicate that flowering ensues whenever the flow of sap is interfered with, whether by the paucity of water or the unhealthiness of the root system.

Problem 3. Another matter which has attracted our attention is that there appears to be a very close relation between richness and purity of juice and vigour of growth. The first requisite in a seedling cane is a high percentage of sucrose and purity of juice, but the total quantity of sugar is what is aimed at in the field, and this will obviously depend upon vigour of growth and the number and size of millable canes in the crop. The first year's seedlings when analysed and weighed showed a markedly converse relation between purity and vigour. The smallest and most meagre plants had the richest juice and those seedlings which were distinguished by the abnormal vigour of seedlings were very poor indeed in sucrose content. Richness and purity, if dependent on lack of vigour, may to all intents and purposes be regarded as a diseased condition and, if so, must be very carefully distinguished from purity and richness which are inherent and varietal. Among my colleagues, Mr Parnell has drawn my attention to a similar relation in indigo seedlings between meagre leaf production and richness in indigotin, and Mr Anstead states that, in analyses made by him of individual rubber trees in South Indian plantations, the latex richest in rubber was obtained from poorly grown or stunted trees.

Problem 4. One important line of work in the cane-breeding station is the selection of suitable parents and inducing them to flower together. But, even if we are successful in this, we are confronted with another serious difficulty. How shall we determine if seedlings obtained are really crosses? We can approach this problem either directly or indirectly. In the first place we may actually cross the two varieties with scientific precautions against self-fertilisation. This has been successfully carried out in Barbados for several years. In Coimbatore there are special difficulties in the way. The bulk of the canes arrow during the heart of the north-east monsoon, a period of violent winds and torrential rains. As the long stalk of the inflorescence (arrow) is very easily damaged and the slightest bend appears to cause it to wither, we have to erect over each arrow a gallows-like support, with a hanging iron cage covered with muslin—much after the plan adopted in Java. The difficulties in crossing such inflorescences can be readily imagined. There are an enormous number of flowers on each arrow and the male

and female organs mature at practically the same time. For certain crossing it will be necessary to emasculate all the flowers of one parent arrow. Even if we succeed in cutting off the majority of the flowers without injuring the rest, each experiment would mean the erection of a lofty staging with practically a glasshouse at the top in which an assistant could use a dissecting microscope. The state of the weather would usually render futile any less cumbrous arrangement. This is at present out of the question. Certain, direct crossing does not at present appear to be feasible at Coimbatore and, added to this, the outlook for such work is discouraging because the results obtained at Barbados appear to have been unsatisfactory, one after another of the carefully nurtured crosses having been abandoned on being tested in the field.

There are two ways which suggest themselves of approaching the problem of obtaining known crosses indirectly. It has been noted that the different cultivated varieties of sugarcane vary a great deal in the development of their essential organs. Some have never been observed to flower: others have flowers which do not emerge from the enveloping sheaths: yet others have partial or total sterility in male (or female?) organs, while a number produce healthy arrows with good pollen and fertile ovules. The commonest case at Coimbatore is that only a certain percentage of stamens open. If we could obtain a variety in which no pollen is formed at all or no stamens open (and there seems to be a close relation between the two, stamens which do not open not containing fully formed pollen and the converse), crossing that variety with one producing good pollen would be easy. One or two such cases have already been observed and crosses obtained, but these happen to be of little value from the economic point of view. The best local cane at Coimbatore, the 'Vellai,' arrows freely every year but produces comparatively little good pollen. Advantage has been taken of this during the past year to pollinate this variety with about a dozen others, in the hope of obtaining crosses between them. The withered flowers of each arrow are kept and carefully analysed as to the percentage of open anthers, and the probability of obtaining crosses or selfed seedlings is calculated therefrom. But, unfortunately, some open anthers are always noted (often about 2 %) in Vellai, and we shall have to depend on further study of the seedlings before we can definitely say whether we have been successful.

A second way of approaching the problem indirectly is opened for us by the fact, now observed for two years, that certain varieties produce

many seedlings, when selfed, which, however, die off at a very early stage. In one case 13 survived out of 4000 in the first year, and a hundred or two out of 10,000 in the second. This would appear to be a varietal character, and two other kinds appear to share this peculiarity. It is, therefore, proposed to pollinate these three, if possible, from other good kinds during the next season on the chance of obtaining a more vigorous lot of seedlings. If we succeed in raising thereby a large number of vigorous seedlings, it may be safely assumed that the bulk of them will be crosses.

Problem 5. It has been suggested that it may be possible to decide the parentage of seedlings by observing their subsequent habit and growth, but we shall require for this purpose a very complete knowledge of the morphological differences of the parents. The problem of classifying the canes thus acquires additional importance. Considerable progress has been made in this direction during the past year and a half. A remarkable number of minute distinguishing characters have been recorded in examining the different canes collected, although this work is still far from complete. A few of these characters may be mentioned here and those interested in the subject are referred to a paper on " The Panjab Canes " about to be published as a Memoir of the Indian Agricultural Department. In this paper a summary of the chief characters studied up to date is given, in order to explain the descriptions of the canes figured.

The habit of the cane as it strikes the eye appears to be extremely important and characteristic. Its erectness, tillering power, shooting of buds, rooting at aerial nodes, leaf angle and leaf endings, as well as liability to be attacked by certain fungi, form useful determining characters. The joint (made up of a node and the internode above it) varies in thickness, length, shape, number, growth curve (the relative length and thickness in different parts), ovalness, hardness of rind, quantity of fibre, juiciness, richness and other properties of the juice, colour, waxy bloom and relative development of leaf scar, circlet of hairs, root zone, growth ring, bloom band, etc., in different varieties. The bud presents important details as to shape, size, mode of bursting, flanges (lateral expansions of basal scales), vestiture in bristles, basal patches of hairs and minute black hairs. The lamina, leaf-sheath and ligule all show similar acts of diagnostic characters, in which various types of hairs play an important part, the leaf-sheath especially presenting a surprising number of differences. As a result of this minute morphological examination of the canes, there appears to be some

prospect of arranging the Indian canes into a series of alliances, although it is not always possible to determine whether similar canes from

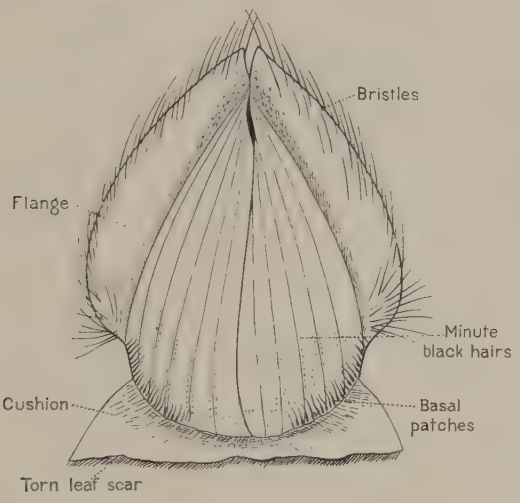

Fig. 8.

different localities are permanently separable or merely local varieties induced by their special surroundings. A natural system of classification is being attempted in which the members of the different groups

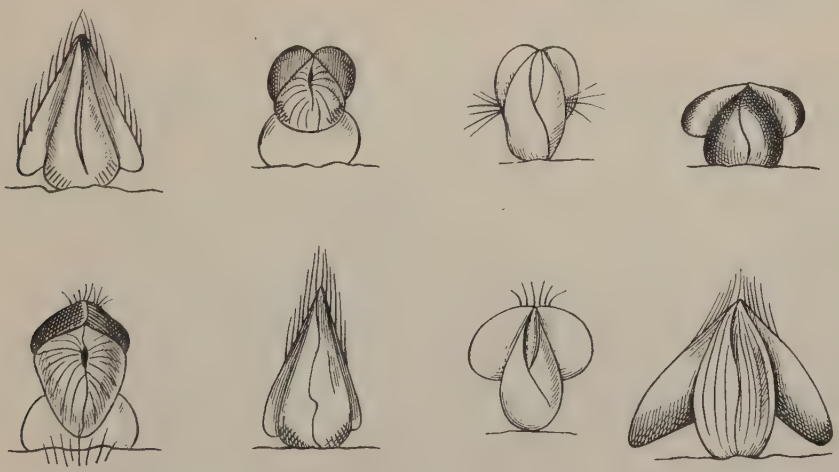

Fig. 9.

resemble one another in as many as possible of the characters referred to above. In such a system agricultural, botanical and chemical characters will all have a place.

Problem 6. The question now naturally arises, are these characters

constant in different localities and under diverse conditions? What stability is to be expected in such minute vegetative separating marks and what are the limits of variability, especially in quantitative characters? There is no doubt that the sugarcane responds very readily to change of habitat. This fact will increase the scope of the detailed study described in the last section, in that the same varieties must be studied for several successive seasons both in North India and at Coimbatore. We already know of characters which are unstable in certain varieties under changed conditions, although they appear to vary less in others. The ivory markings in the joint are usually a good character, but in some kinds of cane they are readily affected by changes in climate (moisture?). The colour of the cane has been observed to change in some varieties in transfer. Canes which appear to be immune to fungus attacks in one district are at once attacked and destroyed by the same species of fungus in another. There are a number of other characters which have been noted as varying in this way, and it is possible that, while firmly fixed in certain kinds of cane, they are variable in others. These facts will naturally increase our difficulties when we attempt to trace the characters of any parent in a seedling by observing its morphological characters. But, in consideration of the facts noted in the next paragraph, it will be seen that these difficulties are greatly increased.

Problem 7. Of what value are the characters noted above in separating seedling canes? Are any of the minute differences observed in varieties propagated vegetatively handed down unaltered in seedlings derived from them? At present there is not sufficient material available to answer these questions. But one of the most obvious features in any batch of seedling canes from a common parentage is the extraordinary amount of variation among them. And this is especially noticeable in those characters of habit which appear to be so stable and valuable in varieties in the field. The seedlings appear to differ in every direction—habit, joint, colour, leaf, juice, etc. We have already collected a certain amount of material for the detailed study of this question. Last year we obtained 70–80 seedlings from Strakarchynia (a thin Behar cane) fertilised by *Saccharum spontaneum*; 13 from Chin (a thin U.P. cane) also fertilised by *Saccharum spontaneum*, and 71 selfed seedlings of Saretha (a thicker cane of the U.P.). As far as time has permitted, a detailed study has been made of these seedlings and the descriptions of them recorded, and it is hoped that, when these descriptions are analysed, some useful facts may be obtained. One difficulty is encountered, however, in our inability to apply the

Fig. 2. A canefield in Madras.

Fig. 3. A canefield in Behar.

Fig. 4. A canefield in the Panjab.

Fig. 5. Cane seedlings at Coimbatore.

Fig. 6. Cane arrows, left Vellai, right Ashy Mauritius, middle *Saccharum narenga.*

Fig. 7. Arrows protected from casual pollination.

Fig. 10. Saretha cane in the field.

Fig. 11. Selfed seedlings of Saretha cane

stereotyped description of cultivated canes (*Saccharum officinarum*) to the wild *Saccharum spontaneum*, for this species is regularly propagated by seed all over India, and the seedlings appear to vary so much among themselves in certain characters that individuals may be placed in almost all the groups already marked out among the cultivated forms. This, however, is a fact not without its significance in our efforts to trace these cultivated forms from *Saccharum spontaneum* itself.

The attempt to determine the parentage of seedlings by their morphological characters of their vegetative parts is thus beset with difficulties, and these are not decreased by the possibility of many characters being intermediate or recessive in the offspring.

Taking these uncertainties into consideration—and there are, naturally, many chemical and agricultural ones not yet fully grasped—the main line of work in the cane-breeding station for the present lies in the direction of selecting suitable parents, preserving the healthy offspring of the best of these, analysing the juice after the first year's growth and observing the relative vigour of growth and choosing the best for further observation—a narrowing circle in which ultimately a few of the best all-round will remain to be sent to the chain of agricultural stations in the north for a renewed series of tests there before dissemination among the cultivators. In all cases it will be our aim to cross good North Indian canes with good South Indian or Exotics, and in the case of the former the importance is recognised of choosing one parent which is largely grown and valued in the particular part of India to which it is intended to send the resulting seedling for trial.

EXPLANATION OF FIGURES.

Fig. 1. Map of India indicating roughly the northern and southern tracts over which sugarcane is grown. The acreage under cane is ten times as great in the northern region as in the southern.

Fig. 2. A modern canefield in Madras.

Fig. 3. A good canefield in Behar.

Fig. 4. A good canefield in the Panjab.

Fig. 5. Cane seedlings at the Cane-breeding Station at Coimbatore.

Fig. 6. Cane arrows, in left of Vellai, in right of Ashy Mauritius. In the middle, the arrow of *Saccharum narenga*.

Fig. 7. Arrows protected from casual pollination (at a village ten miles from the cane-breeding station).

Fig. 8. A typical sugarcane bud.

Fig. 9. Various forms of sugarcane buds.

Fig. 10. Saretha cane in the field—a moderately thick North Indian variety—with very characteristic, erect and ascending shoots.

Fig. 11. Selfed seedlings of Saretha cane. These vary from strict, erect to absolutely prostrate seedlings. The latter are seen in the foreground (left) and the prostrate habit is fixed in all descendants produced vegetatively from them.

THE PEA THRIPS (*KAKOTHRIPS ROBUSTUS*).

By C. B. WILLIAMS, B.A., F.E.S.

(*The John Innes Horticultural Institution, Merton, Surrey.*)

(With 12 Text-figures.)

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History.

Although no doubt damage has been caused to peas and beans for many years by thrips, apparently the first record of such an occurrence is found in 1871 when A. Müller[1] describes shortly, without however mentioning any locality, an attack on peas, which was certainly due to the species here discussed.

In 1880 Westwood gives a much fuller account of an attack at Oxford, with figures of the damaged flowers and characteristically curled pods. He gives the name *Thrips pisivora* to the black-tailed yellow larvae, which were in numbers on the damaged plants, under the impression that they were the adult females, and only just mentions

[1] All references will be found under author and year in the Bibliography at the end.

the real adult as a black winged form which he supposes to be the male! As his name was given to the larval stage it has to be given up in favour of Uzel's name of fifteen years later.

In 1890 Kirchner shortly described damage to peas in Germany as due to *Thrips cerealium*. This name, however, was at that time used to designate any Thysanoptera, and, as in 1897, he figures the orange black-tailed larva, there is no doubt that he was dealing with the present species.

In 1895 Uzel described *Physopus robusta* occurring in various flowers in Bohemia.

In 1898 the Board of Agriculture of England published a leaflet (revised in 1905) entitled *Pea and Bean Thrips, Thrips pisivora*, in which an account is given of damage to field and garden peas and beans and also to scarlet runner beans (*Phaseolus vulgaris*). A copy of two of Westwood's figures is given and an account of the life-history which is either due to mistaken observations or else should apply to some other species. It is stated that the eggs are loose in the flowers, that the nymph or pupal stages are found in the flowers and that the insect hibernates as an adult. This latter belief, which has become very widely spread, has caused many entomologists to recommend the burning of the pea sticks during the winter, a proceeding which, as will be seen, is quite useless.

In 1899 Trybom gave a very full account of a bad attack by the larvae of *Physopus robusta* on peas near Stockholm and in Ostergotland in Sweden. The attack was worst at the end of July and became so bad that the whole plot had to be dug up and burnt. The larvae were found in the bunches of unopened leaves at the growing points and caused these to shrivel up; they attacked the pods, causing them to discolour and curl. Eggs were found embedded in the tissue of the plant at the bases of the young leaves and stipules. No pupae were seen nor were any obtained by keeping the larva in captivity.

In 1900 Theobald described an attack of Thrips in scarlet runners (*Phaseolus vulgaris*) at Crawley, Sussex. This must have been due to some other species, as he does not mention the dark tail to the larva and found the pupal stages in the flowers and also that the adults hibernated. From the figures it would appear to be a species of *Frankliniella* and may be *F. intonsa* which I have found commonly in scarlet runners. In 1906 and 1907 the same author gives accounts of attacks on peas which were undoubtedly due to *K. robustus*.

In 1908 Warburton published an account of this pest and described

the eggs which he found embedded in the tissue of the stamen sheath. He also believed that the insect hibernated in the adult stage. He suggests as a remedy 'topping' the plants as is done in beans for 'black-fly,' as he found that the topmost shoots were most badly attacked.

In 1913 I myself gave a preliminary account of the life-history, showing that it is single brooded and passes the winter as a full fed larva in the soil beneath the infested plants.

In 1914 Vuillet (ii) described a Chalcid *Thripoctenus brui* n. sp. which he found among larvae and adults of the pea thrips in France and which he believes to be parasitic on it.

Recently [Williams, 1914] I have separated the species *robustus* from the genus *Frankliniella* and have erected for it a new genus *Kakothrips* on characters which will be given later. There are several shorter or less important references which will be discussed as occasion arises.

Species and Synonomy.

Although several different species of thrips may at times be found in peas and beans, there is one in particular which seems always to be present in large numbers when any severe damage is recorded. This is at present known to systematists as *Kakothrips robusta*. It belongs to the family *Thripidae* of the sub-order *Terebrantia* of the Thysanoptera.

To the unaided eye it appears as a minute black insect about a twelfth of an inch (2 mm.) long, linear, more or less pointed at each end, with short slender antennae. There is a lighter band across the thorax due to the bases of the wings being pale coloured. The lighter rings on the abdomen described by several authors are merely the soft and lighter coloured connecting membrane between the abdominal segments which shows when the body is distended, usually by killing in alcohol.

As the literature on the Thysanoptera is very scattered and often difficult to obtain, the following notes on the characters of the family and sub-order are given:—the sub-order *Terebrantia* is chiefly characterised, and may be easily recognised, by having the terminal segments of the abdomen more or less constricted to a point (in the *Tubulifera* the tenth segment is tubular), by having a saw-like ovipositor in the female and two longitudinal veins more or less distinct in the front wing. The family *Thripidae* has the antennae six to eight segmented and the ovipositor of the female curved downwards.

Genus Kakothrips *Williams* 1914.

Characterised as follows:—antennae eight segmented, maxillary palps three segmented. Labial palps two segmented. *Ocellar spines between the posterior ocelli.* Fore vein of the front wing set regularly throughout its whole length with spines. *Short lateral processes on each side of the eighth abdominal segment in the male, curving backwards and upwards; rudimentary but distinguishable in the female.* Larva with 9th and 10th abdominal segments dark coloured.

Type *K. robustus* (Uzel 1895).

The characters in italics distinguish it from the genus *Frankliniella*[1] Karny, to which it is closely allied.

Kakothrips robustus.

—— Müller 1871.

Thrips pisivora Westwood 1880. Board of Agriculture leaflet 1898 and 1905. Theobald 1900, 1906, 1907. Collinge 1906. Warburton 1908.

Thrips cerealium Kirchner 1890, 1898.

Physopus robusta Uzel 1895. Trybom 1899. Buffa 1907.

Thrips physapus von Schilling 1898.

Euthrips robusta Bagnall 1908.

Frankliniella robusta Williams 1913. Vuillet 1914.

Kakothrips robustus Williams 1914.

Female (Fig. 1).

Measurements. Head, length 0·170 mm., width 0·190 mm.; prothorax, length 0·200 mm., width 0·250 mm.; pterothorax, length 0·380 mm., width 0·340 mm.; abdomen, length (not extended) about 1·10 mm., width 0·40 mm.; wing, length (from tip of basal lobe) 1·15 mm., width (about half-way along) 0·09 mm.

Antennae	1	2	3	4	5	6	7	8
length (μ)	24	46	74	70	54	68	12	18
width (μ)	40	30	26	26	22	22	10	8

Total body length of living specimen 1·85 mm. (usually 2 mm. or over in specimens killed in alcohol), antennae 0·4 mm.

Colour. Whole body, legs and antennae dark brown, except for the third and base of fourth antennal segments, the tarsi and fore tibiae, which are paler. Fore wings heavily tinged with brown, lighter at the base, hind wings almost transparent.

Head broader than long, cheeks almost parallel. *Eyes* dark not protruding. *Ocelli* present, forming an equilateral triangle; crescents distinct. Two small setae in front of the anterior ocellus and one on each side near the margin of the eye.

[1] Uzel's *Physopus* (=*Euthrips* Hinds) was split up by Karny (1907) into five genera, one of which was *Physapus*. This name being already occupied it was changed (Karny 1910) to *Frankliniella*. The type of this latter genus is *F. intonsa* Trybom (=*F. vulgatissimus* Uzel).

The two long ocellar spines are between the posterior ocelli. A long spine behind each eye and two pairs of short ones in a row between these. A few short forwardly directed spines on the cheeks. Faint striations near the hind margin of the head. *Mouth cone* short and rounded, reaching about three-fifths across the prosternum. *Maxillary palps* three segmented, the second segment shorter and the third longer than the first. *Labial palps* two segmented, the basal joint very short. Antennae more than twice as long as the head; the 1st segment short and broad, barrel-shaped; the 2nd broad and truncate at apex; 3rd the longest with short pedicel and dorsal forked trichome; 4th spindle-shaped slightly broader at the apex than at the base, with ventral forked trichome; 5th narrowing slightly in the distal third

Fig. 1. *Kakothrips robustus*. Female.

and then truncate; 6th spindle-shaped; 7th shorter and broader than 8th. Colour: 1 and 2 dark, 3 and basal half of 4 light yellowish-brown, apical half of 4 and 5, 6, 7 and 8 dark.

Prothorax wider than long and longer and wider than the head. Two long spines at each hind angle and one at each front angle, also two not quite so long on the front margin, and four or five pairs of short ones on the hind margin, the inner pair being longer and stouter than the others. A few minute setae scattered over the pronotum. Very faint striations near the hind margin. *Pterothorax* large, front angles rounded. *Legs* normal, all tarsi yellow, fore tibiae paler than femora. The small projection on the front tarsus noted by Uzel (1895, Fig. 55) is not always distinct. Two rows of stout spines on the hind tibiae. *Wings* reaching to the ninth abdominal segment. Fore wings clouded with brown except at the base; 25–30

spines on the costa, 17–20 on the fore vein, and 13–16 on the hind vein. Hind wings clear, the single vein indistinct but distinguishable to near the tip of the wing.

Abdomen. The ventral pleurites pectinate posteriorly. A very short projection on each side of the eighth abdominal segment (corresponding in position to the much larger ones in the male). A row of short pointed tooth-like projections on the hind margin of the eighth tergite. The tenth segment longer than the ninth and split dorsally for about three-quarters of its length from behind.

Male (Fig. 2).

About one-sixth smaller than the female. All the antennal segments, especially the first two, much paler than in the female. On each side of the eighth segment is a short process curving backwards and upwards and ending in a blunt point. The

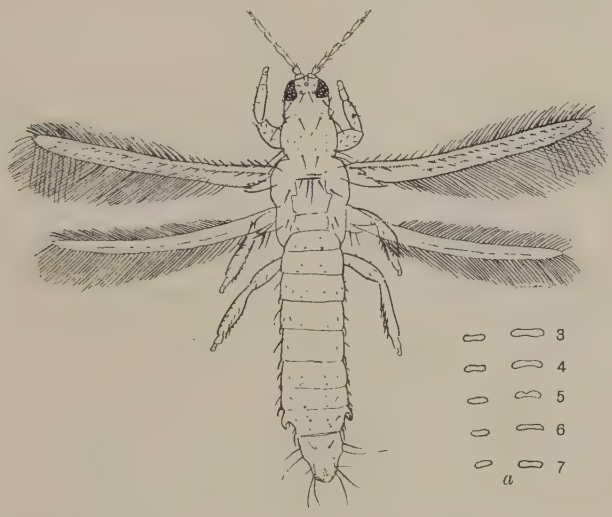

Fig. 2. *Kakothrips robustus.* Male. *a*, outlines of two forms of clear areas on the third to seventh abdominal sternites.

transparent areas on the 3rd–7th sternites are elongate, but vary slightly in outline as shown in Fig. 2 *a*. Otherwise similar to the female.

Uzel's type specimen is in the Bohemian Landes Museums, Prep. No. 13, but as there is no doubt as to the identity of the species the above description has been made from British specimens.

Separation from Frankliniella intonsa.

The only other closely allied species which occurs in peas and beans and with which the pea thrips might be confused is *Frankliniella intonsa*. This can, however, be distinguished by the absence of the

lateral processes on the abdomen in either sex and by the following other characters:

K. robustus.	*F. intonsa.*
Size larger 1·85 mm.	Size smaller 1·3 mm.
Colour very dark in both sexes.	Colour slightly paler in female, male light.
3rd and base of 4th antennal segments light.	3rd, 4th and base of 5th light.
Long ocellar spines between the posterior ocelli.	Long ocellar spines between the posterior and anterior ocelli.
3rd and 10th abdominal segments equal in length.	10th abdominal segment longer than 9th.

Habits of adult.

Time of appearance. In the south of England the adult insects usually appear from the middle to the end of May. The earliest date observed in 1912 was the 28th May, in 1913 23rd May, and in 1914 the 16th May. Several correspondents speak of damage due to 'Thrip' earlier than this but have never been able to supply me with specimens. In the north of England it is later; in Sweden (Trybom) adults were first noticed on the 1st July, while, on the other hand, Gaumont and Vuillet (1914) found it in France at the end of March.

The first specimens are found in the terminal clusters of unopened leaves and in the just opening flowers. Specimens collected at this time contain a large number, sometimes even a majority of males (*e.g.* 16. v. '14 Merton, 9 ♂♂ 4 ♀♀ in flowers of *Vicia faber*). Later in the year the proportion of males becomes smaller and they soon disappear. With the exception of one dead specimen found at the beginning of August (Kendal, Westmorland) I have found no males after the end of June and, indeed, very few after the middle of this month. The females, on the other hand, gradually increase in numbers to about the middle of June (later in the north) and remain more or less common till towards the end of July, and may be found on into August together with full fed larvae on late sown peas. Bagnall (1908) found them in Scabious flowers in Durham as late as "August and September."

The males are more active than the females and escape more rapidly from the flowers when disturbed. The females are often very sluggish and do not leave the shelter of the flower unless this is pulled to pieces.

A female was kept in captivity for over a month and then only died by accident. It is probable that they live much longer than this.

Pairing takes place in the manner usually found in this group. It has been described and figured by Buffa (1907, p. 48) for *Aeolothrips fasciata*. The male climbs on the back of the female with its front legs on the thorax of the latter and the end of its abdomen curled underneath that of the female.

Parthenogenesis. Although the males are quite common early in the year and pairing has been observed to take place, yet the eggs are quite capable of developing parthenogenetically; eggs laid by a female bred in captivity and known not to have paired developed in the normal manner. In many other species of Thysanoptera parthenogenesis is quite normal, in some the male being still unknown.

The adults do not readily take to flight and when they are forced to do so it is usually only for a very short distance. I have no evidence as to whether they are capable of long sustained flight and migration, such as is the case with the corn thrips (*Limothrips cerealium*).

The food of the adults consists, like that of the larvae, of the juices of the plant, which are taken in by a piercing and rasping action of the three stylets in the mouth. They usually confine themselves to the soft tissue inside the flower and also suck the pollen.

The actual act of *oviposition* has not been observed in this species, but in a closely allied species *Taeniothrips primulae*, which lays more openly in the leaves and flower-stalks of the primrose (*Primula vulgaris*), it seems likely that the egg flows gradually into the slit made by the ovipositor similar to the method recently described for a sawfly by Chapman (*Trans. Ent. Soc. Lond.*, 1914, p. 173). Although the egg is very large compared with the size of the insect, it could not be seen to pass in bulk into the prepared slit.

The Egg (Figs. 3, 4 and 5).

The egg is, as is typical for this family, soft, opaque white and more or less bean-shaped but varies slightly in contour, sometimes the head end being more projecting (Fig. 3). It is 0·35 mm. long × 0·25 mm. broad and is large compared with the size of the parent. It is laid embedded in the tissue of the plant, in a slit made by the ovipositor. The slit is at an angle to the surface and the posterior end of the egg is at the bottom, while the anterior (head) end is at the opening quite visible from the surface and often projecting slightly above it.

By far the greater number of eggs are laid in the outer surface of the sheath round the stigma or young pod formed, in leguminous

plants, by the united stamens. This 'stamen-sheath' is very soft and succulent and forms a very suitable environment for the soft egg and also food for the freshly emerged larva. As many as 70 eggs have been counted in a single stamen sheath of *Vicia faber*.

Eggs are also laid, in smaller numbers, in the young developing pod, chiefly at the apex, where it projects beyond the stamen-sheath, or at the base where there is an entrance to the interior between the two edges of the sheath; in the petals (keel, alcae, and rarely standard); in the calyx; and also in the young shoots and leaves in the terminal clusters. This latter situation seems to be rare in this country; I have only

Fig. 3. Eggs. Much enlarged.

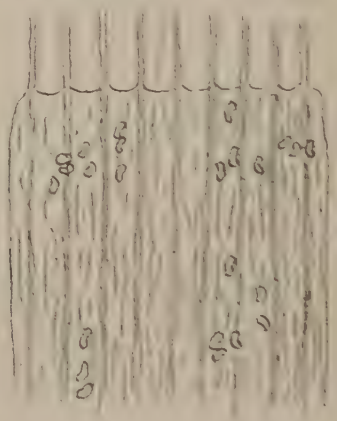

Fig. 4. Eggs in stamen-sheath of Pea. Diagram.

found a very few eggs there, but Trybom (1899) mentions it as the chief place of oviposition in the attack he observed in Sweden.

About five to seven days after being laid two red eye-spots appear at the head end of the egg. These, as pointed out by Warburton (1908), make the egg quite conspicuous in the pale yellowish-green of the stamen-sheath. Two or three days later (total 7–10 days) the young larva emerges.

Larval Stages.

First stage larva (Fig. 6).

The young larva as it emerges from the egg has the antennae bent down below the head, but either before or just after freeing itself from the shell they take up the normal position. The larva is now about

0·5 mm. long, semi-transparent white; the abdomen being unexpanded the legs appear very large in comparison, the hind legs reaching back almost to the tip of the abdomen. The abdomen extends rapidly on

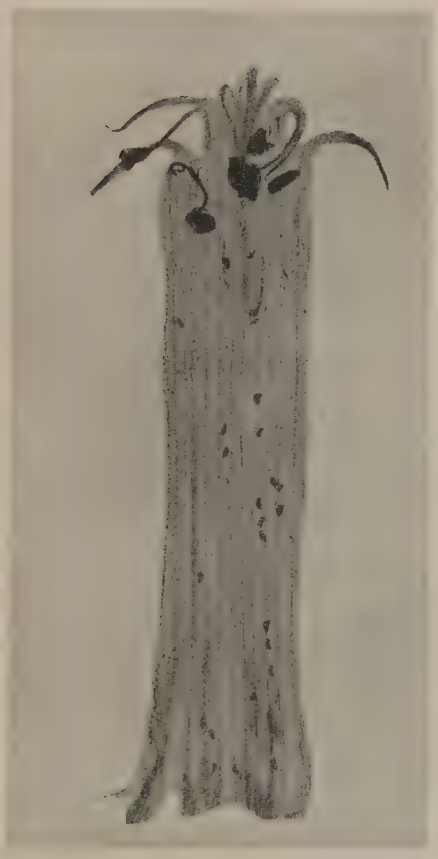

Fig. 5. Micro-photograph of stamen-sheath of broad bean with eggs of pea thrips. × 6.

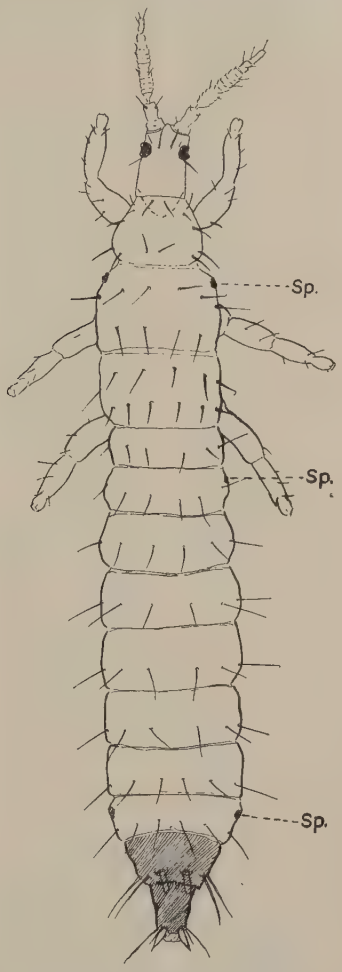

Fig. 6. First stage larva. *Sp.* = spiracle.

feeding and the last two abdominal segments begin to darken. After two or three days the body colour changes gradually to orange but does not become so bright as in the next stage.

Description of first stage larva.

Measurements. Total length varies from 0·5 mm. when just hatched to 1·1 mm. when about to cast its skin.

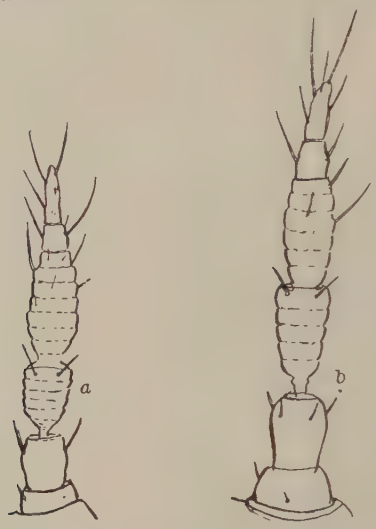

Fig. 7. Antennae. *a* of first stage larva. *b* of second stage larva.

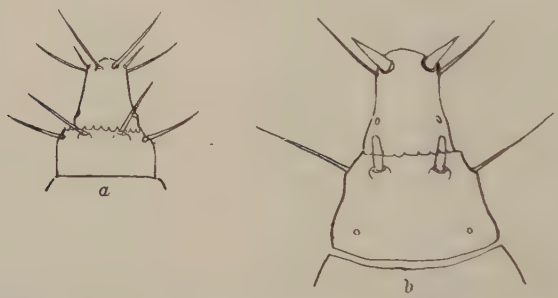

Fig. 8. Ninth and tenth abdominal segments. *a* of first stage larva. *b* of second stage larva.

Width of head across eyes 0·080 mm.
Length of ninth abdominal segment 0·040 mm.
Length of tenth abdominal segment 0·060 mm.

Antennae	1	2	3	4	5	6
length (μ)	18	28	40	54	12	30
width (μ)	31	25	25	27	12	9

Total length of antennae 0·18–0·2 mm.

Antennae (Fig. 7 *a*) six segmented, the third and fourth segments divided by narrow non-transparent rings into sub-segments. There are five or six of these

rings on the third segment and six on the fourth. The fourth segment is slightly wider than the third.

The darkly coloured ninth abdominal tergite is about one-third shorter than the tenth segment. On the hind margin of the ninth segment are six long spines (two dorsal, two dorso-lateral, and two ventro-lateral and two short ventral ones), on the tenth, six long and two short spines. The hind margin of the ninth tergite is furnished with a number of small sharp teeth (Fig. 8 *a*).

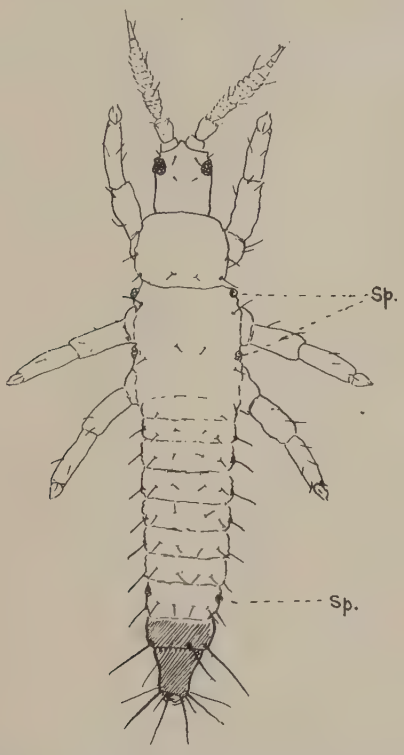

Fig. 9. Second stage larva. *Sp.* = spiracle.

The earliest date that I have found this stage was the 29th May 1914, the latest 29th July 1913.

Eight or nine days after hatching the larva casts its skin and enters on its second stage.

Second stage larva (Fig. 9).

This is about 1·6–1·8 mm. long, bright orange with the last two segments of the abdomen dark brown. The head and legs are now small compared with the much distended abdomen.

Description of second stage larva.

Measurements. Total length 1·4–1·8 mm.
Width of head across eyes 0·09 mm.
Length of ninth abdominal segment 0·08 mm.
Length of tenth abdominal segment 0·08 mm.

Antennae	1	2	3	4	5	6
length (μ)	23	40	50–60	64	17	32
width (μ)	32	29	28	25	17	12

Total length of antennae 0·20–0·24 mm.

Antennae (Fig. 7 *b*) six segmented, the third segment divided into five rings and the fourth into six. The fourth segment slightly narrower than the third.

The dark coloured ninth abdominal segment equal in length to the tenth segment. Near the hind margin of the ninth segment, in the position of the two most dorsal spines in the first larva, are two short transparent processes about 0·040 mm. long and rounded at the tip. On the tenth segment in a corresponding position are two stouter processes of about the same length, but gradually narrowing from the base to the apex which is sharp (Fig. 8 *b*).

The two stages are easily distinguished by the relative and absolute lengths of the ninth and tenth abdominal segments, and by the stout processes on these segments in the second stage which are only represented by hairs in the first.

Both stages of the larvae are found in the flowers and on the developing pods, less commonly in the terminal leaf cluster; as the pod grows and the petals fade and fall off they retire for shelter into the calyx, which forms a cup round the base of the pod. If the larvae have been sufficiently numerous to cause the pod to curl, they will be found chiefly on the concave surface. Should the pod crack or be pierced by other insects they may enter and produce on the inner surface the same characteristic 'silvering' of the surface.

In about six days the second stage larva is full fed. It then descends to the ground and goes beneath the surface to a depth of from three to twelve inches where in some suitable crack or crevice it remains for the rest of the year. There appears to be no attempt at the formation of a cocoon or pupal cavity.

The earliest date in which larvae in captivity have entered the earth was the 28th June (from eggs found on the 8th June), but larvae from eggs laid in May must descend before this. The total time from the laying of the egg to the descent of larva is about 24 days.

The larva remains without moving, in the position it has first taken up, throughout the rest of the summer, autumn and winter until the following spring when, sometimes during March, April or early May, it changes into the propupa or first nymph stage.

Pupal Stages.

The Propupa.

This stage—in which the first wing rudiments should appear and in which the antennae are still free—I have not yet seen. It apparently lasts a very short time. In 1913 the only specimen which survived fungus disease during the previous winter was still a larva when examined towards the end of April and by the middle of May had already reached the pupal or second nymph stage. In the spring of 1914,

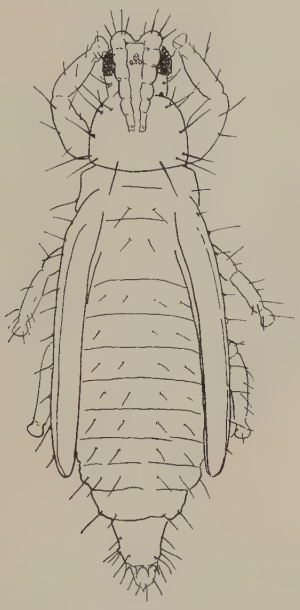

Fig. 10. Second nymph stage or pupa.

owing to an unfortunate misunderstanding, all my infected pots were thrown away by a gardener, but prolonged searching, both by hand and by means of the Berlese funnel, in the soil of a kitchen garden where peas had been attacked the year before yielded many larvae up till the 6th April and a single pupa on the 2nd May.

Pupa or second nymph (Fig. 10).

This stage is assumed during April or May. Normally it does not move from the original position, but when disturbed it walks sluggishly with frequent side to side rocking movements.

Description.

Colour. Head, thorax and abdomen shining orange-yellow. Antennae, legs and wing cases more transparent and almost colourless. The last two abdominal segments are also pale and semi-transparent, not dark as in the larva. The eyes are dark red-brown.

The *antennae* are laid back along the top of the head and reach to about the middle of the pronotum; between them the ocelli are visible. The wing rudiments reach to the seventh abdominal segment. The hind margin of the ninth abdominal segment is produced into several long tooth-like processes. Two long spines near each front angle of the prothorax, two near each hind angle, one near the middle of each lateral margin and one pair on the hind margin. Length 1·6 mm. (measured from life), broad in proportion.

The pupa darkens slightly before the emergence of the adult, but the latter is still pale and soft on escaping. It remains alongside the old pupal skin gradually hardening and darkening in colour for about two days, after which it works its way through the soil to the surface and is ready to start a new cycle of life and destruction.

The life-history of *K. robustus* as described above is very similar to that of *Taeniothrips* (*Euthrips*) *pyri*, the pear thrips. This latter is also single brooded, has two larval stages and spends the greater part of the year as a full fed larva in the earth beneath the infested trees. *Stenothrips graminum*, a species found on cereals in this country and on the continent, also hibernates as a larva deep in the ground (Kurdjumov, 1913).

Distribution.

British Isles.

I have received records or specimens from twenty-nine counties in England, Wales and Ireland as shown in the map (Fig. 11) and below, but so far have not any record for Scotland. I have received bags of peas from a few localities in that country which were all quite free, and Professor Macdougall, of Edinburgh, tells me that he knows of no record of damage. It is probable, however, that it occurs at least in the south as I had but few correspondents, and, as has been mentioned above, the species occurs on the continent as far north as Sweden. Some of the records below are based on only a few specimens. The districts where it is numerous enough to do damage are chiefly in the south and east; I have, however, one record of damage as far north as Cheshire. The absence of records from counties in many cases only means that I had no correspondents in that district and must not be taken to imply the absence of the thrips from that district.

England.

Berkshire. Reading 1912.
Cambridge. Grantchester 1912, Wicken 1912, Cambridge 1914.
Cheshire. Hale* 1906, Neston 1912.
Cornwall. Lostwithiel 1913.
Derbyshire. Ludlow 1913.
Devonshire. Kingsbridge 1913.

Probable.
Reported.
Widespread. Causes damage.

Fig. 11. Present known distribution of pea thrips in the British Isles.

Durham. Hart and Blaydon-on-Tyne (Bagnall 1908).
Essex (Theobald 1907). Witham 1913.
Hampshire. Romsey 1912, Brockenhurst 1912.
Herts. Penshanger 1912, 1913, Amersham and Berkamstead 1908*.
Huntingdon. St Ives 1912.
Kent (Theobald 1906). Sittingbourne 1912, Shoreham, near Sevenoaks 1912, 1913, Maidstone 1913.
Lincoln. Burgh le Marsh 1913.

Middlesex. Richmond 1912.

Norfolk. Bessingham 1913.

Oxford. Walton Manor (Westwood 1880).

Shropshire. Near Shrewsbury 1913.

Stafford. Weston 1910*, Stoke-on-Trent 1910*.

Surrey. Reigate (Theobald 1906), Merton 1912, 1913, 1914.

Sussex. ?Crawley (Theobald 1900), Hailsham 1912*, Ditchling 1912.

Warwick. Warwick 1907*, Lupworth 1908*.

Westmorland. Kirkby Stephen 1912, Kendal 1912.

Worcester (Theobald 1906). Walford-on-Avon, Evesham and Worcester 1905*, Stourport 1907*, Redditch 1909*, Kidderminster and Studley 1910*.

Yorkshire. Malton 1913.

[The records with an asterisk * were kindly furnished by Mr W. E. Collinge.]

Wales.

Carnarvon. Pwllheli 1913.

Denbigh. Colwyn Bay 1913.

Ireland.

Carlow. Bagenalstown 1913.

Cork. Rochestown 1913.

Dublin. Glasnevin. I am informed that in 1897 a black active thrips injurious to peas appeared in the botanic garden; it is almost certainly this species.

Distribution abroad.

Bohemia (Uzel 1895).

France. Loiret, Darcy, Seine, Marseilles (Gaumont and Vuillet 1914).

Germany (Kirchner, von Schilling).

Italy (Buffa 1907).

Sweden. Stockholm, Ostergotland (Trybom 1899).

Nature and Extent of Damage.

The parts of the plant which suffer most from the ravages of this insect are the young leaves in the terminal shoots, the flowers and the pods. There is no record of the older leaves being attacked (cf. the American bean thrips below). In this country the terminal shoots appear to be infested only when the other situations are not available,

as on a very early attack (May) before the flowers are out, or later in the year on late sown varieties. It was this type of injury that Trybom (1899) describes as being most prevalent in Sweden, when the injuries caused whole terminal clusters to wither. Later when the flowers are

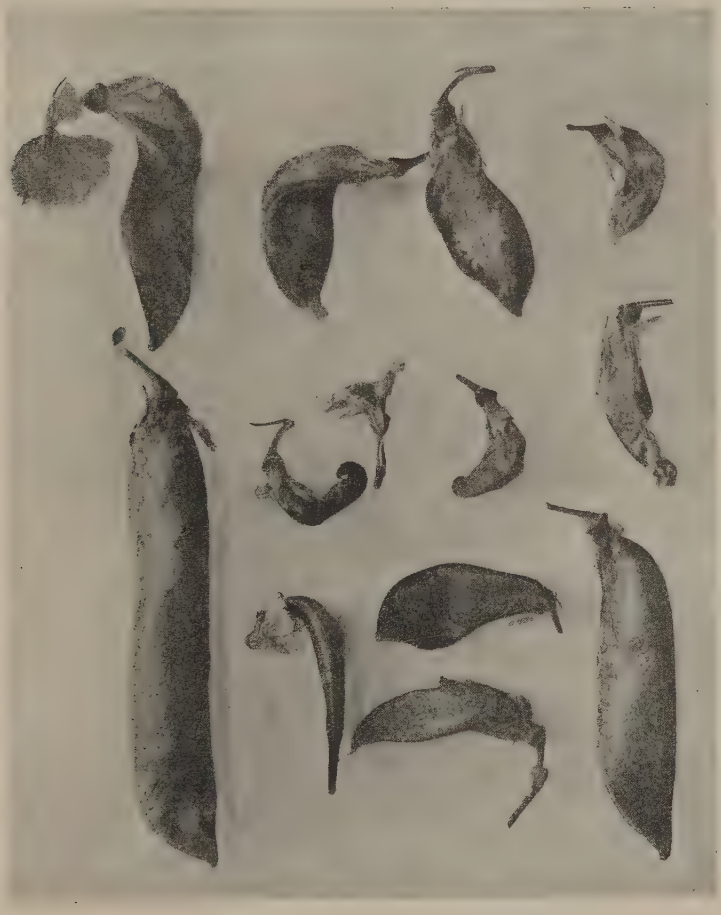

Fig. 12. Pods and flowers of peas damaged by thrips.

attacked these shrivel up and turn brown and in bad cases no pod at all may be formed. Usually, however, it is when the pods are small that the damage is most noticeable; they are sickly, undersized and curled and covered with very characteristic silvery brown areas where the larvae have been feeding. These areas are generally near the base

or the tip of the pod, but often, when the pod is much curled, the whole of the concave side may be 'silvered' (Fig. 12). The silvering is due to the presence of air in the outer cell layers of the plant let in by the sucking of the larvae.

The damage can be very extensive and occasionally the whole crop is spoiled. A correspondent at Sevenoaks, Kent, speaks of "several rows hopelessly ruined," while another at Reading had to give up growing beans because of the injury they suffered, but he unfortunately tried peas instead.

Food Plants.

The species seems to confine itself chiefly to the edible pea (*Pisum sativum*) and the broad bean (*Vicia faber*) and their varieties. Both field and garden crops may be attacked, but the latter seem to suffer more frequently. This may be due to the fact that in fields there is usually a rotation of crops, while in gardens the same crop is often grown on the same plot or quite close by year after year. I have not yet found this species on either sweet peas (*Lathyrus odoratus*) or scarlet runner beans (*Phaseolus vulgaris*), though Gaumont and Vuillet (1914) mention these as host plants in France. Thrips are often abundant on both plants, especially the latter, but, in my experience, always other species (chiefly *Frankliniella intonsa*, *Thrips tabaci*, *Thrips valida*, *Physothrips atrata*), and I am inclined to think that when damage is recorded on runner beans that it is due to one or more of these species and not to *Frankliniella robusta*.

I have also found this species on flowers of knapweed (*Centaurea nigra*) and both Uzel (1895) and Bagnall (1908) have taken it in flowers of *Scabiosa arvense*. Gaumont and Vuillet (1914) mention also *Medicago sativa*, *Cijuga reptans*, *Ecbalium elaterium* and *Coronilla vulgaris*; the two last do not occur in Britain.

Other Species found on Peas and Beans.

Aeolothripidae (*Antennae 9-segmented*).

Aeolothrips fasciatus. Common; easily recognised by its large size and banded black and white wings. Partly carnivorous, but also feeds on pollen and plant juice.

Melanothrips fuscus. Occasional; recognised by its large size and smoky black wings with very distinct veins.

Thripidae.

Frankliniella intonsa. See above (p. 227) for separation. Not infrequent, often common in scarlet runners.

Physothrips spp. (*atrata*, *vulgatissimus* (*pallipennis*)). This genus, which lacks the spine at the anterior angle of the prothorax, contains many species which are only identified with difficulty.

Thrips tabaci. Antennae 7-segmented; colour varying from greyish-yellow to brown; male lighter; common. I have found larvae and pupa of this species on peas.

Thrips physapus. Antennae 7-segmented; colour brown; not uncommon.

Thrips flava. Bright yellow; antennae 7-segmented. This species, which is sometimes common in the flowers, also lays its eggs in the stamen-sheath and other parts of the flower. The larva, however, has not the dark tail which is characteristic of *F. robusta.* It usually appears to be more common when the latter is absent, but I have never found it sufficiently numerous to do any great damage. It also occurs in scarlet runners and many wild flowers.

In the United States beans are much injured by *Heliothrips fasciatus*, which, however, unlike the present species, attacks chiefly the leaves and also spends all its life, including the pupal stages, openly on the food plant, there being several generations during the year. It hibernates as an adult (Russell 1912). Damage has also been reported caused by *Heliothrips phaseoli* (Hood 1912). We have three species of the genus *Heliothrips* in England, but all are confined to greenhouses; there would therefore appear to be little danger of the American species establishing itself in this country.

Kirchner (1890) mentions a species, *Thrips pisi* (Kubler), which would appear from its name to be connected with peas. I have, however, been unable to find the original or any other reference to this name.

Natural Enemies.

Fungus. There was very great mortality of hibernated larvae owing to a fungus which attacked them even in very dry conditions. The hyphae radiated out from the attacked larvae and any other larvae close by became infected in a short time.

Coccinellidae. I was able to feed larvae of *Coccinella bipunctata* in captivity on larvae of the pea thrips, but in the wild state I have never

found the ladybird larvae in the infested flowers, and believe that they exert little, if any, controlling influence.

Chalcidae. Vuillet (1914. ii) has recently described a Chalcid *Thripoctenus brui* n.sp., belonging to the Tetrastichinae, which he found among the larva of the pea thrips at Darcy, Aisne, France, in July 1913. Although he has not actually bred this Chalcid from the larvae, yet there is little doubt that it does parasitise them as it was always found in conjunction with them, and further the only other known species of this genus (*T. russelli*) is parasitic on *Heliothrips fasciatus*, a species which, as mentioned above, is injurious to beans in the United States.

Thripoctenus russelli, or a closely related species, has been taken in England by Bagnall (1914), but I have found no species of this genus as yet among the pea thrips in this country. I have, however, found on several occasions in different localities Chalcids among larvae of the pea thrips, but cannot be certain whether they have any connection with these or not. M. Vuillet has kindly offered to let me have some living specimens of his species if he finds it in sufficient numbers, and an attempt will be made to establish it here.

Other controlling Factors.

Weather. Wet weather always causes great mortality among thrips and also causes the plants to grow more rapidly. In this species, unfortunately, the rain has less effect than usual owing to the sheltered position of the insect in the flowers. However, several correspondents mention that the attack is greatest in dry weather and is lessened by a heavy shower of rain.

Soil. The pea thrips is most prevalent on light soils. In the majority of cases reported to me the soil has been light or gravelly, and a correspondent at Shoreham, Kent, states that the damage is always worse in the village where the soil is light than at Highfield near by where the soil is heavier. It is probable that the conditions in a light soil are more suitable for the hibernating larvae.

Varieties and time of planting. No variety of pea or bean is immune to the attack, but the earlier sown plants usually escape severe damage. As the females lay their eggs chiefly in the stamen-sheath of the flowers, any plants which have passed the flowering stage before the adults become common escape almost entirely. Actual varieties of pea mentioned as having suffered less severely in infested districts are 'Gradus' (an early variety), 'Primus,' and 'Autocrat,' but a careful examination of nearly forty varieties at a seed testing ground at Witham,

Essex, in July, 1913, gave no indication of resistance, except that due to time of planting. In *Report on Field Experiments*, 1912, East Anglian Institute of Agriculture, Chelmsford, it is stated that 'Telegraph' was destroyed by thrips, while 'Gradus,' 'Essex Star,' 'Alderman' and 'Blue Seedling' gave good crops.

Artificial Control.

The habits and life history of this insect make the application of remedial measures of great difficulty. Sprays will not reach the adults or larvae in the flowers, and during the winter the great depth to which the larva descends (they have been found in the wild state more than ten inches below the surface) makes the application of gas lime or soil fumigants of doubtful value. In March of this year numbers of larvae were found deep down in a plot of soil which had been heavily limed last autumn.

When plants are attacked late the larvae, however, are often found in numbers feeding openly on quite large pods. At such a time spraying with any contact spray (soft soap, rosin, etc.) should give good results. On a small scale the following has been found successful

Stock solution

Water	1 qrt.
Soft soap	3 oz.
Tobacco powder	3 oz.

The whole boiled for a short time and diluted for use about one part to twenty of water.

When only a small area is attacked fumigation of the soil during the winter with carbon bisulphide, gas lime, creosote, or such trade products as vaporite or creol should give good results, provided that it is done to a sufficient depth. Experiments are now in progress to test carbon bisulphide-oil emulsion recently described and which it is hoped may prove satisfactory.

Whenever possible a rotation of crops should be practised and peas and beans grown as far as possible from the areas attacked in the previous year.

Traps employing *benzaldehyde*, *anisaldehyde* and *cinnamyl aldehyde* as attractive agents, as described by Howlett (1914), were tried and found to be of no use. These aldehydes have no attraction for this species of Thysanoptera.

The burning of the pea sticks during the winter, frequently recommended, is of no use. Many thrips may be beaten from the sticks, but not this species (chiefly *Limothrips cerealium* and species of the sub-family *Tubulifera*).

Notes on Methods of Collecting and Breeding.

Thrips for identification purposes are of no use when dry. They should be collected into 70 % alcohol, or a mixture of 70 % alcohol and glacial acetic acid in equal parts. In the latter case they must be transferred after a few hours into 70 % alcohol. The latter method is better for larvae as they are less distended than in the alcohol alone. For critical examination they must be cleared and mounted in balsam as a microscope preparation. I find Grübler's 'Turpineol' the most satisfactory clearing agent as it leaves the insects sufficiently pliable to allow of the moving of the wings and legs into suitable positions.

Living specimens of pea thrips have been obtained from all over the country in parchment bags closed with slide-on paper fasteners. These bags are sent out in suitable boxes with instructions to fill with flowers or pods placed in the bag straight after picking. In this way material was obtained from friends and others who knew nothing of entomology, many not even knowing by sight the thrips in question. Many other thrips and insects were found in the bags in which the plants would keep fresh for four or five days, and the method appears to be worthy of wider application. Most of the bags I used were supplied by Messrs Miller and Sons, Renfield Street, Glasgow, but the bags sold for 'paper bag cookery' also answer quite well. They should, however, be as transparent as possible as some idea of the contents can then be got by holding up to the light before opening.

Eggs were obtained, and larvae bred in small glass tubes plugged with cotton wool. Frequent changing was necessary or the moisture which condensed on the sides of the tubes was a great danger, and the sun should on no account be allowed to shine directly on to the tubes. Larvae were hibernated in beakers filled with soil and in flower pots sunk in the ground. They were also obtained in soil during the winter with Berlese's 'Insect Funnel' which, by means of warmth, extracts all the small insects from the soil which is placed in a sieve at the top[1].

[1] I have given a short account of this in the *Entomologist*, xlvi, 1913, p. 273.

Summary.

(1) Peas and beans in England and Western Europe are damaged by a thrips *Kakothrips robustus* (sub-order *Terebrantia*, family *Thripidae*).

(2) The adults appear from May to August; males only in the earlier part. The eggs are laid chiefly in the tissue of the stamen sheath. They hatch in about nine days. The larvae are orange-yellow with the last two abdominal segments dark brown. There is one moult. The second stage when full fed (about 24 days from the laying of the egg) descends into the ground to a depth of from three to twelve inches.

(3) The full fed larva remains in this position till the following spring when the two pupal stages are passed through and the adult emerges. There is only one brood each year.

(4) The damage is greatest on light soils. No varieties are immune, but early sown plants are less damaged. A chalcid parasite, *Thripoctenus brui*, has been recorded from France, but has not been found in England.

(5) Artificial control is difficult. Spraying is only of use when the larvae are feeding openly on large pods. Soil fumigation during the winter should give good results, but must be done to a sufficient depth.

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THE APPLE SUCKER, WITH NOTES ON THE PEAR SUCKER.

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(With Plates XVII, XVIII and 21 Text-figures.)

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Introduction.

The following pages contain an account of a study of the apple sucker made by Mr Awati at Acton Lodge, Brentford, during the summer of 1913. The fact that the life-history of apple suckers occupies one year implies that in one season no stage repeats itself, and Mr Awati could not repeat or check the observations he made.

The most notable point brought out is perhaps the nature of insecticides; so much spraying is done against apple sucker with so little result, simply because the fruit-grower knows no way of checking his results, that the method here adopted should be of interest to fruit-growers generally. It is quite simple and does give a real check on the results one is getting.

Mr Awati left for India and had not time to fully revise the text, so I have done so. I also express herewith our acknowledgments to Sir John Wolfe-Barry, whose generous provision of the studentship made possible Mr Awati's paper on the Mechanism of Suction in *Lygus pabulinus* (*Proc. Zool. Soc. London*, 1914, p. 685) and the present paper. I hope that the work on apple sucker will be of value to fruit-growers in England, and I think the method of checking it is a real advance on anything hitherto used in this country.

H. M. LEFROY.

The Apple Sucker (*Psylla mali*).

I. *Egg to Larva.*

(*a*) *Distribution of Eggs* (Fig. 21). (Black dots on twigs represent eggs of *Psylla mali*.) The eggs are laid singly on the twigs of the apple trees. They are never found in clusters or groups, but on the contrary they are irregularly distributed on the twigs, which are chosen according to their age. It seems that new twigs (of the first year's growth) are chosen by the female on which to lay the eggs. In some cases I have found that the eggs are deposited on one side while the other is tolerably free from them. It is possible that light may have something to do with this kind of deposition. The eggs are found along the scars (on a twig) left on the leaf petioles.

(*b*) *Description* (Fig. 1). An egg of *Psylla mali* is oblong, tapering to both ends. It is sculptured into fine little circles. It is pale white when laid, but begins to change colour when it nears the hatching season, then it becomes distinctly pale brown or reddish. At one end there is a long stalk which hangs free in the air, while at the other there is a sucker-like expansion which glues the egg to the twig. Its position on a twig is such that its long axis lies parallel to that of the twig.

(*c*) *Hatching.* The eggs begin to hatch when spring sets in. If the weather is warm before the spring they may hatch earlier, but generally the larvae begin to come out in the last week of March. I have seen an egg hatching on March 23rd; the hatching may go on for some time, until the last week of April.

(*d*) *Mechanism.* The eggs are split up longitudinally (Fig. 2). It seems that there is some mechanism, which is shared partly by the egg and partly by the larva. The spot where the larva comes out is provided with minute teeth which from either side form a dovetailing

device (Fig. 3). At the same time the larva is provided with an egg-breaker on the front part of its head. This egg-breaker consists of some stout spines attached to the flat part of its head. The spines push the dovetailing device apart, and the larva crawls out. There are a number of spines both dorsally and ventrally which keep the sides of

Fig. 1.

Fig. 2.

Fig. 3.

the egg apart, while the larva is creeping out. The following is a complete diary of a larva hatching out:

27. 3. 13.

10.30 p.m. The larva began to come out.

11.30 p.m. It was completely extruded from the egg but was still attached to it.

11.50 p.m. Sitting at the opening of the egg, moving its antennae and thus taking rest after a great deal of trouble.

2.30 a.m. Quite free from the egg and walking about.

The larva is completely yellow when it comes out and the egg-shell is opaque white. Thus it seems that the change in colour of the egg is due to the larva which becomes brown or reddish as its time for hatching out is nearing.

(*e*) *Behaviour of the first larva.* The larva, after resting a while, begins to crawl up towards the apical bud of that twig. It has a pair of well-developed antennae, the last segment of which is drawn out and

is provided with two bristles. The larva is moving its antennae and is possibly attracted to the bud by a kind of chemotropism; otherwise it is impossible to say why the larva should crawl up towards the bud, which at this time is also sprouting. It sometimes happens that the bud, on that twig, is not yet opened. In that case the larva is at a standstill. It can live without food for two or three days, at the end of which period it succumbs to death. But on the whole, the time for the larva to hatch and the bud to blossom is so finely adjusted, that the former has not to wait for the latter.

II. *Summary of the Life-History.*

There are in all five instars, the last of which is here called the "Nymph," from which the adult insect emerges. Larvae were bred artificially in the experimental house. The method of breeding them was as follows: tender short apple twigs were cut and embedded in

Fig. 4.

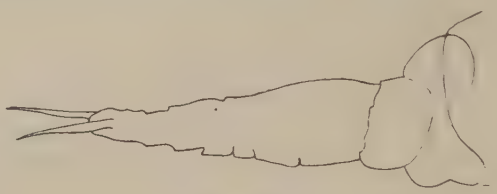


Fig. 5.

Fig. 6.

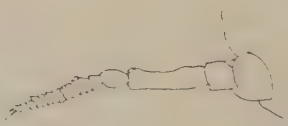


Fig. 7.

wet silver sand in a museum jar, the top of which was covered with a thin piece of muslin. The wet sand enabled the twigs implanted in it to keep fresh for two or three days, at the end of which time they were replaced by fresh twigs. The larvae were carefully picked from the old twigs and placed gently on new ones. Thus it was possible to study them very closely. The temperature of our room was equable and was somewhat higher than that outside. Small apple trees were used for checking the period of each stage, and it seems that this artificial method has no appreciable effect on the life-history of these insects.

The following table shows the period taken by each stage for its moult.

	On twigs in the sand.	On plants outside.
1st instar (Fig. 4).		
1.	23. 4.—30. 4. .. .. 8 days	
2.	21. 4.—28. 4. .. .. 8 days	
3.	25. 4.—ql. 5. .. .. 7 days	
2nd instar (Fig. 5).		There was no time for checking the period of these instars.
1.	18. 4.—25. 4. .. .. 8 days	
2.	20. 4.—27. 4. .. .. 8 days	
3.	26. 4.— 3. 5. .. .. 8 days	
3rd instar (Fig. 6).		
1.	29. 4.—6. 5. .. .. 8 days	1. 26. 4.—3. 5. .. .. 8 days.
2.	28. 4.—4. 5. .. .. 7 days	2. 29. 4.—6. 5. .. .. 8 days.
3.	25. 4.—1. 5. .. .. 7 days	3. 26. 4.—3. 5. .. .. 7 days.
4.	26. 4.—3. 5. .. .. 8 days	4. 29. 5.—5. 5. .. .. 7 days.
5.	30. 4.—7. 5. .. .. 8 days	5. 29. 4.—6. 5. .. .. 8 days.
6.	25. 4.—1. 5. .. .. 7 days	6. 1. 5.—7. 5. .. .. 8 days.
7.	24. 4.—1. 5. .. .. 8 days	
8.	26. 4.—3. 5. .. .. 8 days	
9.	27. 4.—3. 5. .. .. 7 days	
10.	26. 4.—3. 5. .. .. 8 days	
4th instar (Fig. 7).		
1.	1. 5.—11. 5. .. .. 12 days	1. 3. 5.—12. 5. .. .. 10 days.
2.	30. 4.—10. 5. .. .. 11 days	2. 5. 5.—13. 5. .. .. 9 days.
3.	1. 5.—11. 5. .. .. 12 days	3. 29. 4.— 9. 5. .. .. 11 days.
4.	3. 5.—12. 5. .. .. 10 days	4. 1. 5.—10. 5. .. .. 10 days.
5.	29. 4.—13. 5. .. .. 15 days	5. 5. 5.—13. 5. .. .. 9 days.
6.	30. 4.—10. 5. .. .. 11 days	
7.	6. 5.—15. 5. .. .. 10 days	
8.	3. 5.—12. 5. .. .. 10 days	
9.	30. 4.—10. 5. .. .. 11 days	
10.	6. 5.—15. 5. .. .. 10 days	
5th instar or "Nymph" (Fig. 8).		
1.	9. 5.—21. 5. .. .. 13 days	1. 9. 5.—18. 5. .. .. 10 days.
2.	11. 5.—23. 5. .. .. 13 days	2. 12. 5.—22. 5. .. .. 10 days.
3.	10. 5.—23. 5. .. .. 14 days	3. 13. 5.—22. 5. .. .. 10 days.
4.	10. 5.—23. 5. .. .. 14 days	4. 13. 5.—22. 5. .. .. 10 days.
5.	12. 5.—24. 5. .. .. 13 days	At this time the plants were transferred to the frames, where the heat was greater than outside. The variation in the time may be due to this fact.
6.	13. 5.—24. 5. .. .. 12 days	
7.	8. 5.—20. 5. .. .. 13 days	
6th or adult stage (Fig. 9).		June to November.

There were many larvae bred from beginning to end. But I had to replace those that died in the course of breeding. There are peculiarities of each instar by means of which the different instars can be distinguished. These peculiarities will be described below.

Fig. 8.

Fig. 9.

III. *Description of the Instars.*

(*a*) *General description.* (i) *Colour.* A larva of each stage passes through the same cycle, though it is growing bigger in size. It is bright yellow when it hatches out or has moulted. The colour gradually changes to yellow-brown, or in some cases distinctly reddish. This change in colour may be due to exposure to atmosphere. But there is a complete change of colour in the nymphal stage, when it becomes entirely green. The larva of the fourth instar changes its colour from brown to pale green as it matures for the fourth moult.

(ii) *Secretion* (Fig. 10). The larvae of these insects are unmistakeably recognised by their secretion. All the larvae, including the nymphs, have opaque white secretion, a long thread of which is hanging out from the hinder portion of the abdomen. This thread consists of a central core of translucent liquid covered externally by the whitish material which prevents its exuding and thus wetting the surface of a leaf. The larva begins to secrete as soon as it hatches out or has moulted. The thread in some cases reaches a great length; at the end there is a big knob-like swelling. If the thread is pricked, the translucent liquid exudes and wets the surface. This secretion is of a waxy nature and is soluble in alcohol. Besides this big thread issuing from the anus, there are small spine-like threads projecting from the extremity of the abdomen. They are shining and seem to change colour, which is not their intrinsic

property as some investigators think, but it is due to the refraction of light; this is clear since the colour seems to change as one sees it from fresh points of view.

Fig. 10.

... *Heart-Shaped Organ* (Figs. 12, 13, 14). (*a*) *External appearance.* Every larva has this characteristic organ, which is cordate in shape (Fig. 12) and is bordered with several rows of big pores, besides which there are also minute pores in many tiers inside the boundary.

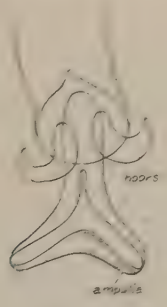


Fig. 11.

In the centre of this organ there is a peculiar-shaped structure which is due to the invagination of chitin. Just above the notch of this organ is an aperture presumably functioning as the anus or the opening of the waxy glands. On either side of this opening there are two

strong spines which may direct or support the thread of secretion alluded to above.

(*b*) *Internal structure* (Figs. 13, 14). Inside this heart-shaped organ are situated two kinds of glands both of which are of a waxy nature. The larger of the two finds its exit through the aperture mentioned above. This is demonstrated by the longitudinal section (Fig. 13). It is a big coiled structure occupying the whole of the abdomen of a larva and secreting the big thread of wax mentioned above. The other consists of small glandular cells opening out through those pores referred to already. They secrete fine, shining, small spine-like threads

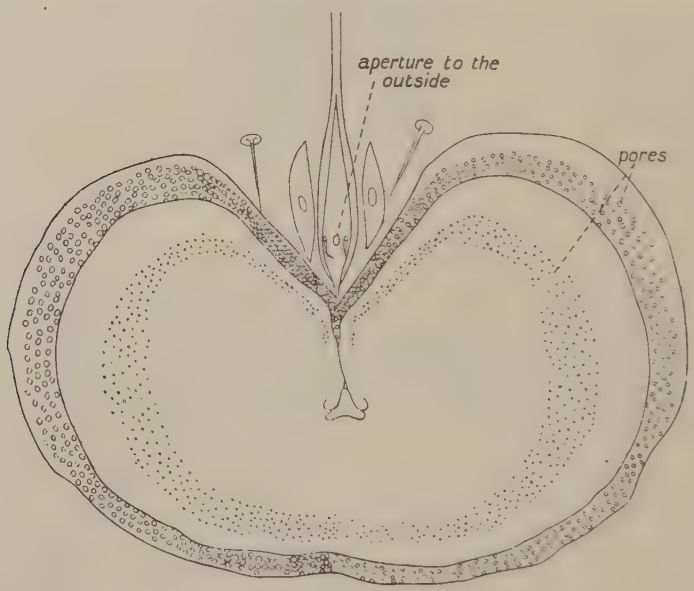


Fig. 12.

projecting from the extremity of the abdomen. This structure will be clearly understood from a transverse section (Fig. 14). This organ with the glandular structures is left behind when the nymph moults to the adult insect. There is not a trace of these structures in the adult, which does not secrete honey-dew.

(iv) *Wing Lobes.* These begin to appear in the third instar. In the second instar their places on the meso- and meta-thorax are already marked, but in the third there are small protuberances in these places. They become well developed in the fourth instar, while in the nymphal stage they are broad and elongate, lying at the sides. There are also small

vestigial nervures on them, though the whole appearance is entirely different from the wings of the adult insect.

(v) *Claws* (Fig. 11). It is not necessary to describe the legs of a larva in detail, inasmuch as it does not differ from those of any ordinary insect. But their extremities are very interesting. There are two strong curved spines, in the midst of which there is a sucker-like organ which has

Fig. 13.

Fig. 14.

a big hollow cup (ampulla). These claws are adapted for the larval life as the larva has to crawl on the waxy and slippery hairs of the apple-buds. The ampulla enables the larva to fix its leg very firmly on the surface, while the spines may help the larva in locomotion.

(vi) *Eyes.* The larval eyes are red or reddish in hue, though in the nymphal stage the colour changes to dark green, while in the adult the eyes are distinctly black.

The larvae are distinguished from stage to stage; the distinction being in the increase of the number of segments of the antennae. The first and last segments seem to remain unchanged, and the rest are intercalated from instar to instar. The external appearance of the last segment with its two bristles is very characteristic through the whole life-history of *Psylla mali*.

The following table will give the characteristic differences of the antennae of each instar:—

Instars	No. of segments
1st instar (Fig. 4)	2
2nd „ (Fig. 5)	3
3rd „ (Fig. 6)	4
4th „ (Fig. 7)	5
5th Nymph (Fig. 8)	7
6th Adult imago (Fig. 9)	9

IV. *Habits of the Young Insects.*

A description of the habits of the larvae or the insects in general can never be too important nor too detailed, since the basis of insecticides is founded on that. The more we know of the habits of an insect, the easier does it become to kill it.

(i) *Chemotropism.* The larvae are positively chemotropic, their antennae are very well developed, especially the last segment with its two bristles. The first larva, as soon as it is hatched, crawls towards the apical bud of the twig. It is moving its antennae in the air. The larva seems to be attracted by a smell emitted by the bud, to which smell we seem to be insensible. The same phenomenon is repeated in other instars, which are all attracted to the buds by means of some chemical substances.

(ii) *Heliotropism.* All the instars except the nymphs are negatively heliotropic. They avoid light and are always found in the dark recesses of the bud. As soon as they are brought to daylight, or an artificial light (electric) is brought to bear upon them, they try to avoid it. It is this habit which enables them to find the tender leaves of the buds inside. The nymphs, on the other hand, are positively heliotropic. As soon as the fourth instar moults for the nymph, the latter leaves the darkness of the bud and comes to live on the open under surface of the leaf. This change of habit may be beneficial to an imago emerging from it, as the latter must have an open surface to fly.

(iii) *Thigmotropism.* This is peculiar to these larvae, except the nymphs. They are positively thigmotropic, *i.e.* they react positively

to pressure. The leaves of the buds are pressed against each other and the larvae like to be among those closely packed leaves. This habit combined with (ii) is very advantageous to them, since both habits enable the larvae to get at the most tender leaves of the buds. The nymphs, on the contrary, are negatively thigmotropic. They avoid being pressed together and come to live free, uncrowded on the open surface of the leaves.

(iv) *Gregariousness.* All the instars, except the fifth, are gregarious in habit. They are found crowded together, and try to come together however much they may be separated from one another. I have tried many cases when the larvae were put separately on different buds of the same twig. On the second or at most the third day they were found to be together. This gregarious habit of the larvae is extremely useful since one can kill all of them in one lot. The nymphs, however, are never gregarious. They are always separated from each other and try to avoid the neighbourhood of other larvae and nymphs as well.

(v) *Powers of endurance.* The larvae can live without food for two or three days, after which they collapse and die. The fact that they can thus exist temporarily is very beneficial to the first instar, as it may not immediately find a fully-opened bud on its twig.

(vi) *Situation.* The larvae are always found in the recesses of the buds. They are rarely found outside, except in the nymphal stage, when they are found on the under surfaces of the leaves. The buds infected by them can easily be recognised. They are all covered with the waxy threads hanging down like icicles. The nature of the threads has already been described above. The position of the larvae in the bud seems to be fairly constant. The head is turned away from the growing point of the apex of the bud and the abdomen is turned towards the apex. In the case of nymphs, the position is very indefinite. The larvae, when sucking, press themselves down against the surface of a leaf and the whole body seems to be heaving up and down as the stylets are withdrawn or thrust into the leaf. The length of the stylet is enormous. In all stages they are twice or thrice as long as the whole body.

V. *Effects produced by the Larva.*

Psylla mali is most dangerous to apple trees in its larval stages. While in the adult, it does practically no damage. As described above, the larvae are gregarious in habit and plenty of them are thus found in

a single bud. Each larva thrusts its stylets deep into the tissues and begins sucking the juices. The suction-pumps of the larvae are at work night and day sucking the juices of the bud until it completely dries up. The leaves become brown, as if they were frost-bitten, wither, and drop down one by one. The buds, both floral and foliage, are thus destroyed wholesale and the apple trees cannot, of course, bear any fruit. If there is any remedy to be applied, it should be applied when the insect is in the larval stages. It seems that the growth of the buds (floral and foliage) runs parallel with the development of the *Psylla mali*. Soon after the flowers are set, *Psylla mali* is in the adult stage, when it does no damage. There are other effects produced indirectly by these larvae. They soil the bud-leaves by the secretion of waxy substances when the threads of secretion are broken up. The translucent stuff of the core exudes and covers the surface of the leaf. Particles of dust get glued to the leaf. In fact the wax forms an impervious layer over the surface. This may interrupt free transpiration of the leaves, which may thus be smothered and suffer. It is, however, curious that no fungus is seen growing on the leaves thus wetted by the larvae. This effect is not universal and may only be found in some places.

VI. *The Adult.*

(*a*) *The external sexual differences.* (i) Both sexes seem to be alike in general appearance, though there is an obvious difference in the shape of the genitalia. In the male they are curved and turned upwards, while in the female they are straight and pointed and lie concealed in the upper and lower anal segments. Their anatomical description in the female only will be given below in the reproductive system.

(ii) *Colour differences.* The colour of the male seems to be brown or at the most pale green; it is never green nor deep green; while the females are nearly always deep green. The colour in both the sexes changes with the age of the insects, but it never becomes uniform in both the sexes.

(iii) *Abdomen.* The abdomen of the female seems to be broader when it is fertilised, while that of the male is very narrow and tapering.

(*b*) *The proportion of the sexes.* In the beginning of this investigation it was suspected that there was parthenogenesis among these insects. If so there would be a disproportion among the sexes—the females outnumbering the males. To solve this question the adult insects were caught at different times from the period they emerged from

the nymphs to the time when they laid eggs. The results of those different catches are given below:—

Time	Female	Male
May 27, 29	40	36
June 2	39	51
16	34	32
19 and 24	97	99
July 2	44	38
9	36	46
Aug. 12	49	47
22	24	23
	363	372

It seems clear that there is no great disproportion in the sexes and no reason to anticipate parthenogenesis.

Habits of the Adults.

(*a*) *Change of colour.* The adults, both male and female, undergo some change in colour as they grow older. The uniform brown, pale green, or deep green gives place to a tinted pattern of the same. Some females of reddish brown have been found.

(*b*) *Feeding habits.* The males and females sit on the leaves—either on the upper or lower surface. They are very harmless in this stage, though they produce certain characteristic symptoms of their presence. They suck the juices of those leaves, which become marked with very minute circular white spots. These spots seem to increase in size and afterwards the spotted surface disintegrates and small holes are formed. Thus the presence of *Psylla mali* in the adult stage can easily be recognised. Another class of insects (Jassids) also produces white spots, but these can be easily distinguished from those of *Psylla mali* by mere observation.

(*c*) *Flight.* They are rarely seen on the wing unless disturbed. Then they seem to jump forward with their hind legs and take a short flight—from leaf to leaf or twig to twig.

(*d*) *Habitat. Psylla mali* seem to choose the under surface of leaves, though they are sometimes found on the upper. In the adult stage they are not confined to apple trees alone, but seem to migrate to different plants interspersed with the apples. They are found on gooseberry bushes, pear trees, plums, etc., besides apple trees. This migration may explain how the infestation is carried from one orchard to another, because their powers of flight would not sustain them in direct migrations from one apple-orchard to another.

VII. *Tracheal System* (Figs. 15, 16).

From the economic point of view none of the internal organs of an insect is of more importance or deserving of more attention than the tracheal organs. They constitute the chief medium through which a contact-poison insecticide acts. Prof. Lefroy has proved this point by his experiments on meal worms. The tracheal system differs in different insects, as also in the larva and the imago of the same insect, specially with regard to the way the respiratory organs open to the exterior. In some insects the spiracles lead directly to the tracheae, while in others there are various modifications for closing and opening the mouths of the tracheae. This difference in the arrangement of the

Fig. 15.

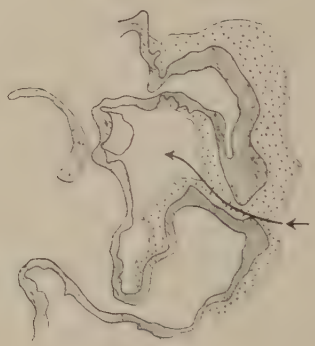


Fig. 16.

spiracles and the tracheae may explain why a certain insect with simple tracheae succumbs to an insecticide more easily than others with modifications of the tracheal apparatus. In *Psylla mali* there are two kinds of trachea, one in the imago and the other in the larvae, including the nymphs.

(i) *Tracheal system in the imago* (Fig. 16). It is of the simplest. The outer integument is invaginated to form a spiracle which leads directly to a tracheal trunk. There is a structure in the spiracles which may function as a strainer of the air which is sucked through the spiracles. The structure of a spiracle of this kind may be easily understood from the figure.

(ii) *Tracheal system in the larvae* (Fig. 15). This system is extremely complex. There are various devices between the external opening and the tracheal trunk, which are:

(*a*) *The spiracles* (three on the abdomen and two on the thorax) are situated in a pit which is covered over with long hairs.

(*b*) *The external lid of the spiracle.* This is formed by a thick process which lies across the spiracle.

(*c*) *The closing apparatus.* It consists of thickened chitin stretching from the one side of the tube to the other. It is acted upon by the spiracular muscles which are attached to this apparatus. When these muscles contract, this transverse bar of chitin is pulled apart and the spiracle is opened.

(*d*) *Atrium.* Below the closing apparatus is a cavity which communicates with the main tracheal trunk.

The simple structure of the spiracle of the adult and the more complex structure of that of the young lead one to infer the adult will react more readily to an insecticide and this is actually the case. In experiments with insecticides, I found that the adults died as soon as the emulsion reached them, whereas the young struggled for some hours before succumbing. The progress of the insecticide into the adult is unchecked, whereas it is obstructed in the larva; it has, in the latter case, to pass the hairs before it reaches the spiracle, and it cannot then pass the closing apparatus till paralysis is set up, opening the valve and giving it unrestricted entrance to the tracheae.

VIII. *Reproductive System* (Figs. 17, 18, 19, 20).

(i) *The reproductive system* does not begin to develop until the adult stage is reached, though the indication of this system is early seen in the fourth and fifth instar, in which the external sexual differences begin to be visible; the males (the larvae which are going to become males) being short and the females longer.

(ii) *Coupling.* Coupling begins in the first week in June, but the eggs are not laid until September. The coupling members lie side by side dorso-ventrally, their heads being turned in the same direction. This is a very characteristic position of these insects.

(iii) *The reproductive organs of the female.* Primary. These consist of the following parts (Figs. 18, 19, 20):

(1) *Ovaries* (Fig. 19). They consist of small egg-tubules, from

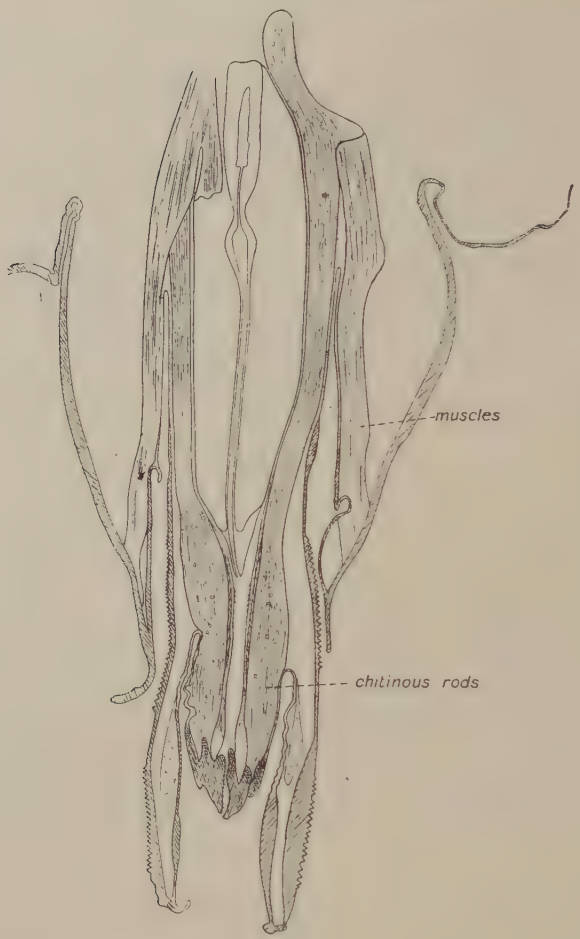


Fig. 17.

Fig. 18.

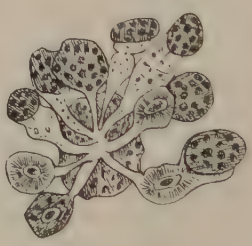


Fig. 19.

eight to nine on either side; each tubule is composed of three or more cells. Each tubule ends in a cell full of nuclei which may give rise to the egg-nucleus. This kind of ovary has

(2) *Oviducts* (Fig. 18). There are two oviducts, one on each side. The ovarian tubules open into them, and they in their turn open into the vagina as a single duct. The oviducts are coiled and nearly bent upon themselves on their way to the vagina, with which they communicate ventrally after they have formed a common duct.

(3) *Vagina* (Fig. 20). This is a single median muscular sac, communicating externally through the ovipositor. There are circular muscles which seem to be very powerful.

Fig. 20.

(4) *Accessory glands* (Fig. 20). They open into the distal part of the vagina. They consist of two kinds, one larger than the other, the smaller opening into the larger. At the entrance into the vagina there are muscles which regulate the opening of these glands.

(5) *Spermathecum* (Fig. 18). There is a single median spermathecum lying ventrally below the vagina, and the oviducts. It opens into the distal part of the vagina by a duct which runs dorsalwards. This spermathecum is used for storing the sperms. The vagina changes in structure distally and opens into the tube formed by the ovipositors.

Secondary characters. The ovipositors (Fig. 17). This structure is

formed by the invagination of some of the posterior segments of the abdomen. They consist of the following parts:

(1) Supra-anal segment.
(2) Infra-anal segment.
(3) Chitin rod on each side, ending distally in a pointed structure.
(4) Muscles attached to these chitinous rods.

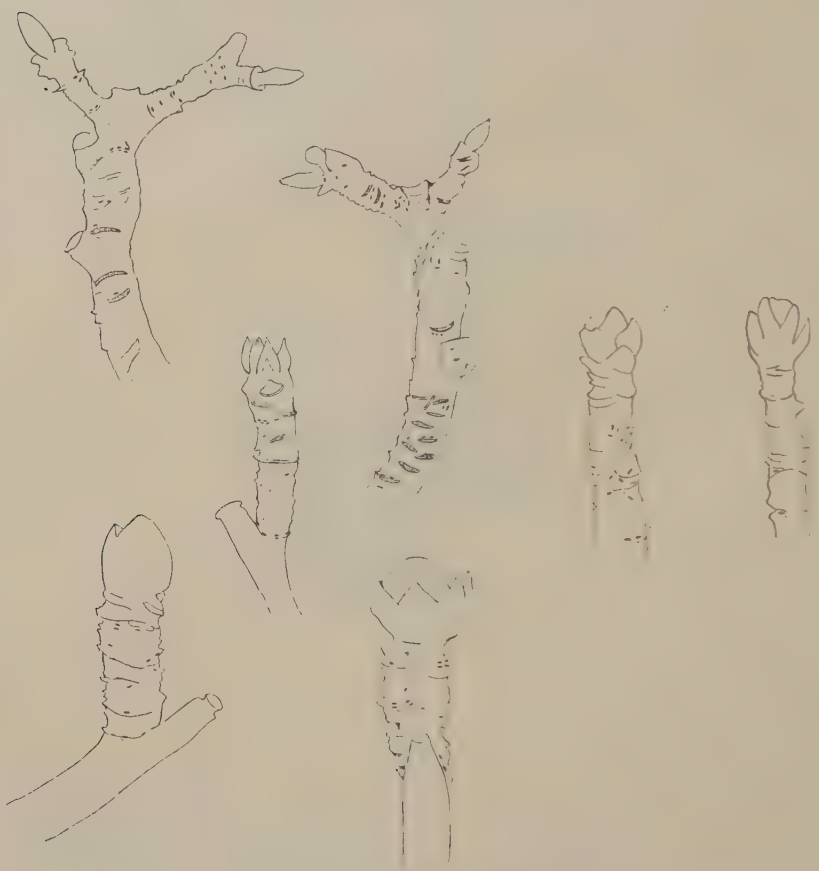


Fig. 21. The Eggs on Twigs.

(iv) *Oviposition.* The points of the chitinous rods, between the vagina opening, are concealed by the supra- and infra-anal segments. When the muscles, which are attached to the proximal ends, contract, the chitinous rods are pushed forward and the points project further than the anal segments which are applied to the surface of the twig. The egg, which is pushed forward by the circular muscles of the vagina,

enters the cavity formed by the ovipositors. Distally there are recurved minute hairs which prevent the egg from going back. One egg is laid at a time.

(v) The maximum number of eggs produced by a female in one case was 30, in another 37.

(vi) *The egg-laying season.* This is very short and only extends over a week. The females began egg-laying early in September. By the middle of the month the season was over.

(vii) The males and females seem to outlive this egg-laying season for some time. They are found as late as October and they appear to die towards the end of that month. In November I could not find any specimen of the *Psylla mali.*

IX. The Pear Sucker (*Psylla pyricola*).

This insect is the most important pest of pear trees on the Continent and in America. Unfortunately, it has recently been found in the United Kingdom, and was reported last year by Prof. Theobald, of the Wye Agricultural College. This insect has the same life-history as *Psylla mali*, but there are many important differences and features which make this insect more formidable than *Psylla mali.*

(1) *Eggs.*

They are elliptical and narrow. Their colour varies from pale yellow to brownish yellow. They are found in clusters or groups of 30 or more on the upper surfaces of leaves but scarcely on twigs. They can easily be distinguished from those of *Psylla mali.*

(2) *The Larvae* (Plates XVII, XVIII).

(i) There are five stages, the imago emerging from the fifth (or the nymph). The first four stages correspond closely to those of *Psylla mali* in the external structure, but the fifth instar or the nymph is very characteristic of this insect. It is not uniform in colour but is spotted on the abdomen. The other structures seem to be similar.

(ii) *Secretion.* These larvae exude a waxy secretion which wets the surface of a leaf. There are no white threads as there are in *Psylla mali.* The larvae of *Psylla pyricola* are always wallowing in the secretion. On this honey-dew grows the injurious fungus which has been identified by Massee (of the Royal Botanical Gardens, Kew) as *Cladosporium herbarium.* Thus it will be seen that the habits of these larvae as to secretion are quite different from those of the larvae of *Psylla mali.*

(iii) *Situation.* These larvae are always found on the open surfaces of the leaves of the pear trees. Their responses to surroundings have not been observed.

(iv) *Injurious effects produced by larvae.* These effects are two-fold:

(*a*) Effects due to *Cladosporium herbarium*, the Sooty Mould.

(*b*) Those due to the larvae. The larvae suck the juices of the leaves and thus starve them. The leaf becomes curled and withered and afterwards dries up. When the leaves die the metabolism of the whole plant is interfered with and thus the plant may ultimately be killed.

(3) *The Adult.*

(i) The imago is green when it emerges from the nymph, but it soon becomes dark in colour. The external structures with reference to sex are identical with those of *Psylla mali.*

(ii) *Feeding habits. P. pyricola* do not produce any white spots on the leaves, but on the other hand they produce rather injurious effects. The adult insects secrete honey-dew and wet the surfaces of the leaves, on which grows the same injurious fungus.

Thus *P. pyricola* is injurious in both its stages, *i.e.* in the larval as well as in the adult forms; while *P. mali* is harmful only in the larval form.

(iii) *Reproduction. P. pyricola* is tri-voltine; while *P. mali* is uni-voltine, *i.e.* the former has three generations while the latter has only one.

The following are the probable dates of the three generations of *P. pyricola*:

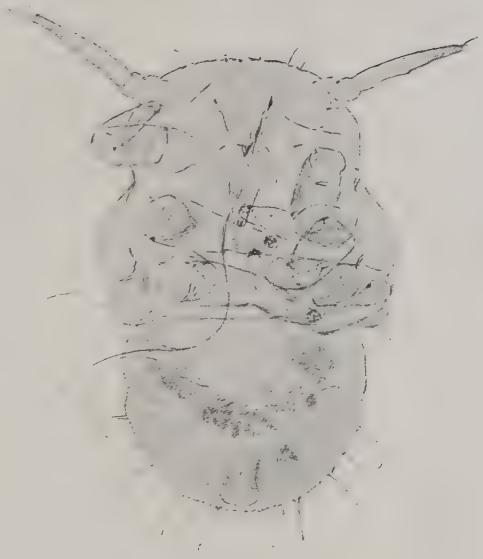
1st generation	..	.. April and May.
2nd ,,	..	.. June, July.
3rd ,,	..	.. August, September.

P. mali has only one generation from March to September. *P. pyricola* hibernates in the imago stage. The adults of the third generation pass through the winter and lay eggs in the following spring when the females are fertilised. *P. mali* hibernates in the egg-stage; the eggs are laid in September and the larvae hatch out from them in the following spring. In short, *P. pyricola*, when compared with *P. mali*, seems to be as dangerous to pear trees. This pest is gradually spreading, though at present it is only known locally. America and the Continent suffer from this pest. It requires more working out. I have given its description as a contrast to *P. mali.*

Apple Sucker. 3rd Instar.

Apple Sucker. 4th Instar.

Apple Sucker. 5th Instar.



Pear Sucker. 4th Instar.

Pear Sucker. 5th Instar

X. *Insecticide Treatment.*

In the course of the investigation of the life-history of *Psylla mali* it was found that the larvae are covered with waxy secretion. As they secrete the waxy stuff the under surfaces of the leaves get soiled by the wax and become impervious to water. The buds besides having a waxy covering have also got minute hairs and other structures of their own which make it more difficult for water to reach them. My task was to find a fluid which would thoroughly saturate the bud leaves and so reach the larvae. I have used different percentages of the soap (soft) solution and found one per cent. of the soap solution satisfactory. One per cent. means ten pounds of soap in 100 gallons of water. But the soap solution by itself was not effective enough the kill the larvae. It was tried on some apple trees with the result that 72 per cent. were killed and the rest were healthy enough. The soap solution not only saturates the bud leaves but it engulfs the larvae also, though in some cases without killing them. The reason why 28 per cent. were living seems to be that the soap solution is very effective if it dries instantaneously. By doing so it blocks the respiratory pores (stigmata) of the insects, which are thus suffocated and killed. This means that the soap solution will be more effective on leaves exposed to the wind and the sun. But in the case of buds the leaves are not so exposed and larvae in these buds do not run such risks as those on the open leaves. The soap solution is not poisonous by itself, and if it does not dry up immediately it is utterly ineffective, for the larvae can be happy in it and crawl out of it before it dries up and their stigmata closed up once for all. This would explain why such a large percentage was living with the soap solution. As the soap solution was deficient by itself, I had to seek some poisonous stuff which would facilitate the action of the soap solution. The stuff had to be one of the wax solvents, and for this purpose I used many things:

(1) Petrol.
(2) Kerosene.
(3) Xylol.
(4) Acetone.
(5) Creosote.

All these are more or less wax solvents. The last reagent proved to be the best on trial and I have made use of it. These reagents do not increase the surface tension lowered by the soap solution and they are miscible with it. It must be remembered, however, that though they are poisonous to the insects and wax solvents, they do a great deal

of damage to plants if used in excess. Before I begin the description of my experiments with regard to different insecticides, it would be correct to state the particular times for spraying apple trees for apple sucker. I was very late last year owing to many difficulties. The proper time for spraying is before the floral buds have opened. The eggs begin to hatch as soon as the foliage buds open and there is a great interval before floral buds blossom. If put off too long the spraying will shake the pollen from the flowers and the ovaries will remain infertile. In no case should there be any spraying when the blossom has opened. The setting season begins and the petals begin to drop off and the fruit become set. Then there is another chance of spraying the stragglers—the nymphs which may have been unfortunate enough in the previous larval stages. This final spraying combined with the previous one will completely exterminate the apple sucker from the orchard.

It is a curious fact that spraying at different times in the day has varying results. The same mixture was sprayed over the apple trees at different times:

	Spraying time		Result
25. 5. 13	12 noon.	It was light and windy and hot.	All died instantaneously.
	5.30 p.m.	It was cool.	All died eventually, but at the time of examination 10 or 11 were still struggling for existence.

These variations can be explained. On a bright, hot, windy day the soap solution dries up immediately and the creosote acts very effectively; while, when it is cool, the insecticide does not dry immediately, and creosote seems to be very slow in its action.

These experiments will at least show that the different times of the same day have different effects, though the insecticide may be the same.

Different washes used.

(1) *Rosin Wash.*

(*a*) *Composition:*

Rosin	2 lbs.
Washing soda	2 lbs.
Water	20 gallons.

(*b*) *Action.* As the stuff gets dried, rosin is deposited on the surfaces of the insects and blocks the air holes, the stigmata; the insects are suffocated and thus killed.

(*c*) *Effects :*

(1) It has not penetrated the buds at all.

(2) None of the larvae were touched by it.

(2) *Paraffin Emulsion.*

(*a*) *Composition :*

Paraffin	.. 2 gallons.
Bar soap	.. ½ lb.
Water	.. 1 gallon.

Diluted 1 gallon to 9 gallons water.

(*b*) *Action.* The fluid is sprayed into minute droplets spread over the surfaces of the leaves—each droplet consisting of two parts—the central core of paraffin surrounded by the outer crust of soapy water. The water then evaporated, and the paraffin core being exposed spread over the surface and the larvae touched by it are killed. The paraffin acts as a contact poison. It has nothing to do with respiration. Thus its action is quite different from that of rosin wash. This is shown by the fact that the larvae do not die as long as there is water, but they do so when the water evaporates and the paraffin spreads.

(*c*) *Effects :*

(1) If used in excess it burns the plants, especially on a bright sunny day.

(2) More than 50 per cent. of the nymphs were killed.

(3) It did not wet evenly. Some drops were resting on the hairs of the bud leaves.

(4) Nymphs were not wetted on the lower surfaces of the leaves.

(3) *Soap-Creosote Emulsion.*

(*a*) *Composition :*

100 gallons of water.
10 lbs. of (soft) soap.
Quart creosote oil (crude, commercial).

I found this emulsion the best of all. Not only is it simple and effective, as it will be presently seen, but it is the cheapest thing on the market. One hundred gallons of the wash only cost 2*s.* 6*d.*, and this price compares favourably with any insecticide available.

I started first of all with the soap solution only, but the results, though not poor, were not very satisfactory. I have already explained why the soap solution by itself is not effective. There is another possibility that the larvae recover the next day. They can withstand suffocation for many hours, and the soap, unlike rosin, does not

completely block the stigmata, rosin being a solid thing. The soap solution has two defects:

(1) It is of use only in case of buds where the leaves are not exposed to the wind and the sun.

(2) The larvae may and generally do recover from the effects of a soap solution after some hours.

The results of the soap solution were (the solution being 1 %):

72 % dead. 28 % living.

In order to remove these two defects the creosote oil was emulsified with it—the oil being poisonous to the insects. These several experiments were tried with differing percentages of the oil, that of the soap (solution) being constant.

(1) With 1-10 or ·1 % of creosote.

22500 cc. water
8 oz. soap
22½ cc. creosote oil
Spraying 2.30 p.m., 24. 5. 13.

The result being:

39 living
74 dead
106 dead
54 living
} Nearly 50 % dead.

(2) With ·2 % of creosote.

4 oz. soap
11200 cc. water
22 cc. creosote
Sprayed at 12.30 p.m.

110 dead
8 living
} Nearly 93 % dead.

(They were dead next day.)

(3) With ·25 % of creosote.

4 oz. soap
11200 cc. water
28 cc. creosote
} There were three trials. Every time the result was that all the larvae were killed by the time of the examination.

(*a*) *The method of the examination.* The observers (Prof. Lefroy, Mr Davidson, Mr Miles and myself) used to wheel the machine to the apple trees. One of the heavily infected apple trees was selected and was sprayed with the driving jet. Each of us then broke the twigs at random and collected them together. Those twigs were brought home and spread in an open space on papers. When they were fully dry Prof. Lefroy picked out the dead and the living larvae, and thus the different results and the percentages were obtained.

The creosote oil is very harmful to plants and especially to tender leaves. It was tested in those percentages used in the experiments

on different apple trees by Prof. Lefroy, who examined those trees next day and found that no harm was done to them. It seems therefore that the creosote oil in the percentage used (·25 per cent.) is not all harmful to the trees.

(*b*) *Its action.* The action of this emulsion is two-fold and therefore very effective. As it is shown above, the soap solution by itself kills 72 per cent. of the larvae. Its action is also explained. The soap solution, by being mixed with the creosote oil, becomes a deadly poison. The soap solution enters the tracheae and blocks the stigmata and thus introduces the creosote poison into the body. It acts both internally and externally, and thus it becomes very effective. There is no chance of recovery for the larvae, as is the case with the soap solution. The percentage of the creosote, however, seems to be fixed—·25 per cent. being the optimum. Below and above it the results are not very satisfactory.

(*c*) *Effects.* They have been already dealt with. The death roll by this emulsion is very great.

XI. *Enemies of the Apple Sucker.*

As far as I have observed there are no enemies. I have not been able to see any parasite, internal or external, preying on it. The larvae are healthy and normal, and I have not seen any malformation owing to its being parasitised. So it is impossible to say whether there is any parasite controlling the growth and spreading of this pest.

Occasionally I have seen mites attacking the nymphs and adults. The mites are red and large—like those which generally attack aphides (aphis). Besides these mites I have not seen any enemy to the apple sucker.

XII. *Immunity of the Apple Trees to the attack of the Apple Sucker.*

There seems to be no reason why there should be immunity to the attack. Immunity may be acquired or inherent. The apple suckers in the adult stages do not make any damage, and therefore there is no pathological response. The inherent immunity may be due to the fact that the juices of certain apple trees may be distasteful to the apple suckers, while those of the others are sought after with avidity. It must be remembered that the real damage is done by the larvae and not by the adults. The larvae suck the juices of the buds and not the fruits. It seems from what I have observed that there is no

difference in the quality of the juices of the different varieties of the apple trees—they seem to be the same, whether sweet or sour, and they are not disliked by any batch of the larvae.

No doubt there are different trees which are less heavily infected than others, and there are some which are not infected at all. I doubt whether the latter form the case of the immunity. The same variety passes through all stages of infection—some with no larvae, while others are heavily infected with them. It seems to be the case of the chance distribution of the eggs of the apple sucker on different plants.

I have noted down the results of my experiment with regard to the immunity:

	Name of the variety	Sweet or sour	Infection
(1)	Duchess favourite	very sweet	none
	,, ,,	,, ,,	fair
	,, ,,	,, ,,	median
	,, ,,	,, ,,	heavy
(2)	Yellow injesting	sweet	fair
(3)	Warner's king	sour	none
(4)	Stirling Castle	,,	median
	,, ,,	,,	fair
	,, ,,	,,	,,
(5)	Early Julian	,,	medium
	,, ,,	,,	fair
(6)	Worcester pearmain	sweet	none

INSECTICIDES FROM A CHEMICAL STANDPOINT.

By W. F. COOPER, B.A. (Cantab.), F.C.S.,
and W. H. NUTTALL, F.I.C., F.C.S.

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As the title implies, this paper puts forward some ideas which, to us, appear to lead to a wider range of choice in insecticidal substances, and to possible improvements in their methods of application.

We are chemists and make no claim to a special knowledge of entomology; yet we have been concerned for some time with the practical control of various horticultural pests and animal parasites, and we venture to hope that the experience thus acquired may be of some little value to the economic entomologist.

On glancing down a list of the substances most generally used in the preparation of insecticides, a chemist is at once struck by the surprisingly small number of compounds which have been employed. It would seem that until recently the changes have been rung on little more than half-a-dozen materials: Bordeaux mixture—lime-and-sulphur—quassia—arsenic—pyrethrum—paraffin, and so on. So-called improvements, which are claimed from time to time, appear as a rule to be confined to some slight modification of one or other of the existing formulae, the number of which is already legion.

In the past the attempts to control entomological pests have been of too empirical a nature. Substances have been tried with little, if any, regard to their precise mode of action, and when a moderately satisfactory material has been found the experimenter has rested content, where he might with profit have continued his enquiries along those lines which this result should suggest. Empiricism generally tends to stifle true research, and genuine progress rarely follows in its train, while patient research on well-organised and systematic lines almost inevitably paves the way to final success.

It is not sufficient to discover that a certain compound is more or less effective for the destruction of specific pests—the further step must

be taken, of ascertaining what particular characteristic of that compound is primarily responsible for the results obtained. For example, in the absence of proof to the contrary, it is not wise to assume that, because tar substances possess insecticidal properties, the latter are wholly dependent upon the presence of phenolic compounds. In the case of coal-tar disinfectants it was the practice until recent times to determine the germicidal value by a chemical estimation of the phenolic content alone, whilst no account was taken of the non-phenolic constituents. It has since been shown, by actual tests on living cultures of bacteria, that some of the non-phenolic constituents may possess an even higher germicidal value than the phenols themselves, and, in consequence, germicidal values of coal-tar disinfectants, based on chemical determinations, have fallen into disrepute. This would have been avoided had a careful examination of the factors which influence the germicidal action of a coal-tar disinfectant been made.

It follows, therefore, that until many, if not all, of the factors which determine the efficiency of an insecticide are known, the observer is liable to draw similarly erroneous conclusions.

Hitherto the economic entomologist in his search for suitable insecticides has confined himself to those compounds which to him appeared to be cheap and easily obtained, but it seems to us that a wide field still remains unexploited, in which, nevertheless, these essential conditions obtain.

There are many organic compounds of probably high insecticidal value, which are readily prepared in the laboratory, and which, if a suitable demand arose, would be commercially possible. The choice of these for experimental trials should not be made in a haphazard manner, but should be preceded by a systematic investigation, so arranged as to determine what particular characteristic conferred the insecticidal property. Two illustrations will suffice to make our meaning clear.

It has been found that xylene is the most effective of the tar hydrocarbons in destroying wood-boring beetles. To what particular property is this superiority due? Does some special grouping of the atoms in the molecule play a part, or is it a purely physical question? If it is a special grouping of the atoms which endows xylene with such a degree of insecticidal efficiency, then it is reasonable to suppose that other compounds with a similar molecular constitution would be equally effective. If, on the other hand, the insecticidal characters of xylene are dependent on its physical properties, then other fluids with identical

physical constants should behave in a similar manner. Unfortunately there is no reliable information at hand to decide the point, invaluable as such knowledge would be as a basis for research on these lines.

Again, the efficiency of carbolic and cresylic acids as insecticides is universally known, and it is reasonable to presume that these compounds possess insecticidal properties by virtue of their phenolic groups. Benzene compounds containing a nitro-group have germicidal properties, and have been suggested as insecticides—as for example, nitro-benzene. It is conceivable, therefore, that the nitro-group, like the phenolic group, may confer insecticidal properties, if introduced into a molecule. Would the insecticidal properties of carbolic or cresylic acid, therefore, be increased by the introduction of one or more nitro-groups? This was the question which the Bayer Farbenfabrik asked themselves as early as 1892, and, as the result of systematic research, they were able to answer it in the affirmative and produce a most valuable insecticide, "Antinonnin." This is ortho-cresol into which two nitro-groups have been introduced, the potassium salt of the resulting compound, owing to its greater solubility, being employed in practice. It is non-corrosive, and attacks neither metals nor textile fabrics. Antinonnin has been extensively and successfully applied in the destruction of the "Nonnen" (*Monacha*) larvae, infesting the forests of Bavaria and Würtemberg; and has also been largely used as a substitute for creosote in the preservation of timber. This affords an excellent illustration of the value of systematic research as opposed to empirical methods.

The subject of insecticidal effect of the introduction of various atomic groups into the molecule needs to be worked out systematically, much in the same manner as that in which Ehrlich carried out his classic investigations on the effect of various organic arsenic compounds on blood parasites. Ehrlich found that the position of the arsenic in the molecule had an enormous influence on the toxic effect of the compound, both on the host and the blood parasite; and, as a result of a long and systematic research, he at length evolved his famous "606," efficacious doses of which, whilst highly toxic to blood parasites, are practically innocuous to the host.

Speaking generally, metals in organic combinations, as distinct from inorganic, are considerably less toxic towards the higher animals and plants, whilst they retain their poisonous action on the lower organisms. This fact suggests the possibility of the use of organo-metallic compounds as insecticides. The insecticidal properties of the metal might

be thereby retained, whilst the injurious effect on the host might be diminished. We are not aware that any organic arsenic compound has been employed in this connection, the principal reason being, possibly, that such compounds are usually too expensive for the purpose; but the use of an interesting organic compound of copper has been suggested. This is cupric-di-methanal-di-sulphite ($Cu(H_2C.OH.SO_3)_2$), which is easily prepared by passing sulphur di-oxide into a suspension of copper hydroxide in 40 % formalin. A clear blue solution, containing 3 % of copper is thus obtained, which, it is claimed, combines in itself a copper insecticide and a sulphuring agent.

The high insecticidal value of emulsions of paraffin or other oils has long been recognised, whilst copper, in one form or another, is in very general use as an insecticide and fungicide. Is it possible to combine the advantages of both? Copper resinate is soluble in mineral oils, so that by emulsifying such a solution of copper resinate, a preparation would be obtained, which might possess the insecticidal properties of both an oil emulsion and of copper.

According to Pickering, the action of Bordeaux Mixture is due to the gradual liberation, by the atmospheric carbon-dioxide, of small quantities of soluble copper sulphate. It is a well-known fact that certain substances are much more reactive when freshly liberated from their compounds. In many cases this is due to their "nascent state"; in others, the extremely fine state of division, in which they are deposited, is doubtless responsible for their increased activity. Atmospheric carbon dioxide might be employed with the greatest advantage in the precipitation of insecticidal compounds in this super-active form, but, with the exception of Bordeaux Mixture, and possibly potassium sulphide, little, if any, use of it has been made up to the present. Let us consider, for example, β-naphthol. This is a constituent of coal-tar; it has high bactericidal properties, and, being a phenol, presumably would act as an insecticide. It is a simple matter to prepare a solution of β-naphthol in caustic soda, so adjusted that a mere trace of carbon dioxide would precipitate a minute quantity of the β-naphthol. Such a solution used as a tree spray might prove to be of the greatest value, because its active constituent would be liberated gradually, and so could only act upon the foliage in extremely minute quantities.

To take another example: preparations containing potassium sulphide (liver of sulphur) are largely used as insecticides. To what particular property these owe their insecticidal action is apparently doubtful. The gradual precipitation of sulphur from the admixed

poly-sulphides is probably largely responsible. But the necessary quantity of carbon-dioxide to effect the precipitation of sulphur from commercial potassium sulphide is very large; consequently the process is slow, and probably some weeks elapse before the beneficial effects of precipitated sulphur come into play. It is, however, not a difficult matter to prepare solutions from which sulphur can be precipitated in an exceedingly finely divided state by a mere trace of carbon-dioxide, and there is little doubt that these would be found more effective than ordinary sulphide preparations.

The efficiency of many insecticides is entirely dependent on the fact that they suffocate the insect by blocking up its breathing orifices. Of this type, viscose suggests itself to the chemist as a most excellent material. Viscose is a derivative of cellulose, which is extensively employed in the manufacture of artificial silk. It is characterised by the fact that even in dilute aqueous solution it forms an extremely viscous liquid, which by exposure in thin layers gives a tenacious and impermeable film. Obviously, viscose preparations could not be used for spraying the entire foliage of trees, but as a winter wash or as a local application, in the case of scale, such are certainly worthy of trial.

So much then for the directions in which a search for new and improved insecticides might be made. Many more could doubtless be suggested, but the foregoing will suffice to indicate the wide field awaiting inquiry.

Quite apart from the quest for new substances, there is another point, which we take this opportunity of emphasizing, because it is one which many economic biologists are apt to lose sight of, in the selection of remedies for the eradication of insect and fungoid pests. This is the extraordinary importance of the *physical condition* of the insecticide in its influence on the efficiency. Attention has already been drawn to the fact that a chemical assay of a carbolic disinfectant is really no measure of its bactericidal power, because it is based on the false assumption that only phenolic compounds have bactericidal properties. But the chemical assay of a disinfectant fails for another reason, and that is because it takes no account of the *physical condition* of the active compounds. It has long been known that, of two preparations containing equal percentages of the same tar acid, *emulsified* in the one case, and in a state of *simple solution* in the other, the *emulsified* preparation possesses a much higher bactericidal power than that containing the tar acid in *solution*. Chick and Martin (*Journ. of Hygiene*,

VIII, 5, pp. 698–703) have shown this to be due to the fact that the bacteria are adsorbed on to the fine emulsified particles of the tar acid and are thus brought into direct contact with the germicidal agent in a highly concentrated form. Now, whatever may be the cause, there is little doubt that, of liquid insecticides, an emulsified one is far more efficient than a non-emulsified one. Whether Chick and Martin's explanation holds good in this case also, is questionable; possibly, with very minute insects, adsorption may play some little part. Where, however, an emulsified insecticide is undoubtedly vastly superior to a non-emulsified one is in its wetting-power, and with insecticides this is a point of paramount importance. It is needless, here, to point out the extreme difficulty of wetting the chitinous integument of an insect, or the protective woolly secretion of the aphis of American blight; nor is it necessary to dwell upon the fact that an insecticide cannot do its work unless it actually comes in contact with the insect: such are self-evident to all who have to deal with entomological pests. Perhaps what is not so generally recognised is the fact that different liquids have very different wetting powers. A simple experiment serves to illustrate this. The American cloth back of an exercise book may represent, sufficiently well for the purpose, the chitinous integument of many insects. When water is poured on to the back of such a book it runs into droplets and flows off without wetting it, precisely as water would run off the integument of the insect. If, however, an *emulsion* is poured on to the book, the whole surface is completely wetted, and the liquid forms a continuous film. If, now, the emulsion is washed off by a stream of water, the unwettable character of the surface again becomes evident, the water flowing into droplets and running off. A liquid insecticide, in order to be efficient, must be capable of thoroughly wetting the insect and its surroundings. It must "*run*" easily and be able to penetrate the interstices of the buds, the folds and crinkles of the leaves, waxy secretions, hairy or woolly surfaces, the minute orifices of the insects themselves, etc.; and experience has shown that liquids of low surface tension, *e.g.* emulsions, are best suited to this end.

There is an additional advantage in the use of an emulsion, which was brought out in a pertinent manner in some work carried out by one of us (W. F. C.) in South Africa four or five years ago. We were then concerned with the eradication of the Bont Tick, which infests cattle and transmits the fatal disease—*heart-water*. Sodium arsenite had long been used as a means of destroying these ticks, but it was found that, at the strength necessary to kill the ticks, the cattle themselves were

frequently so badly scalded that death ensued. By employing an emulsified oil in conjunction with the sodium arsenite and so ensuring complete wetting of the hide, Cooper found that a much lower percentage of arsenite was sufficient to destroy the ticks and that the risk of scalding was practically removed. The scorching of sprayed trees is not an uncommon occurrence, and it is most probable that the means adopted for the prevention of the scalding of animals would also prove effective in preventing injury to foliage.

With solid insecticides or fungicides, such as copper carbonate, lead chromate, lead arsenate, etc., which are usually applied, as aqueous suspensions, in the form of a spray, the physical condition of the solid plays a by no means unimportant part in the efficiency of the preparation. According to the manner of precipitation, these compounds may be obtained in either a coarse granular state, or as a fine light flocculent precipitate. In the first case, the suspension settles rapidly and requires constant attention in the matter of stirring; further, it is liable to clog the nozzles of the spray-pump and, in addition, after drying, is apt to fall from the sprayed leaves. On the other hand, a fine, flocculent precipitate has none of these disadvantages.

These examples will serve to show how very greatly the efficiency of an insecticide or fungicide is dependent upon conditions other than chemical; they indicate that, as with disinfectants, a chemical assay alone must give a wrong impression of the actual value; and these are facts which must not be lost sight of in the consideration of the standardisation of insecticides.

As a matter of fact, we are only just entering upon the scientific study of the preparation and application of insecticides. That our methods have been too empirical in the past is largely due to the lack of co-operation between the economic entomologist and the chemist; neither can hope to achieve real success alone. It is for the entomologist to investigate the various pests, their life history, habits and vulnerability; it is for the chemist to devise and elaborate means of attack, based upon the information supplied by the entomologist and upon the chemical and physical properties of the substances with which he has to deal.

INSECTICIDES.

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It would be interesting to collect information as to the insecticides in general use in horticulture in different countries in any one season and to determine as far as possible what were the circumstances leading to their use. There is, I believe, a fashion in insecticides: at one time Paris Green and London Purple ruled; then came Lead Arseniate in America; this is apparently giving place to Zinc Arseniate and Barium Arseniate, while there is reason to hope that Lead Arseniate, and perhaps Lead Chromate, will be more familiar in this country.

So, too, for contact poisons. I remember the era in America of paraffin emulsions and rosin washes; then came whale oil soap; lime salt and sulphur followed, then the heavy oils and then "miscible oils." The vogue of the lysol and similar mixtures on the Continent has to be noted, and we may note that miscible oils are being used more freely in Australia and South Africa.

In estimating the causes of these successive fashions one would need to distinguish the effect of the recommendations of State Departments of Entomology and the influence, increasing in recent years, of the weight of pure advertising by firms interested in the sale of the particular products they were able to handle. In this paper I omit entirely the "patent" or "proprietary" insecticides in so large use, since it is not always clear on what ingredients their action depends, and I confine myself to insecticides of definite known constitution, or those which depend upon the presence of some known chemical compound.

It is not easy to ascertain exactly what insecticides are at present used on a large scale in this country, but I have tried to do so from three sources: the first is the published recommendations of horticultural journals; the second is the recommendations in the leaflets of the Board of Agriculture; the third is those that I gather from general

information, observation, reports, papers in actual use. For the first I attach extracts from 16 consecutively weekly issues of the *Gardeners' Chronicle* in 1913, these occurring in the contributions of head gardeners or in editorial advice. I think they reflect accurately current ideas and practice.

Hardy Fruit Garden .. For aphides .. The tree syringed with a very mild insecticide. In some cases it will be found necessary to use tobacco powder, which should be left on for two or three days, and then thoroughly syringed off with clear soft water. p. 268, 26. 4. 13.

Abies diseased .. Aphis. Editorial .. Spray three times at intervals of four days, with a solution of soft soap and quassia chips, and repeat the spraying in September. p. 279, 26. 4. 13.

Broad beans .. Black fly .. Syringe the plants frequently with a fairly strong solution of soft soap. p. 280, 26. 4. 13.

Cool orchard house .. The eradication of insect pests can be done either by fumigation with nicotine, or by spraying with some good insecticide. p. 288, 3. 5. 13.

Market Fruit Garden .. Insect pests .. For some unknown reason, insect pests are troubling me at present much less than usually. It is many years since I found so few Apple suckers. Most varieties of Apples in my orchards are almost free from this enemy, and many are nearly exempt from the attacks of aphides and caterpillars. It would be interesting to learn whether this comparative immunity is general or not. If it is not so, perhaps persistence in destroying the pests for years past is meeting with a fitting reward. But it may be that suckers and aphides hatched prematurely during the mild winter or in March were killed by frost. Or, again, spraying with a strong solution of lime-sulphur just before the buds burst may have done something in coating over eggs or destroying mother queen aphides. It is too early, however, to assume that the comparative immunity will continue. There can hardly be a bad attack of the sucker after this; but the aphis and the caterpillar have plenty of time during which to appear in strong force. Already the hope that Plums would escape the usual infestation of aphis has been disappointed. On April 24 no attack could be observed on any but two varieties; but on the 29th there were aphides on all. As the leaves are curled over the pest, spraying would be a mere waste of time and money.

The first summer spraying Owing to the partial immunity of Apples from insect pests, the usual spraying before the expansion of

blossom was to a great extent dispensed with, only varieties which were badly attacked by aphis, sucker, or caterpillar, or all three pests being sprayed. This was a great relief, and it is not by any means certain that it might not have been extended to all varieties without any bad results. For on every occasion rain fell a few hours after the spraying was done, probably washing most of the spray fluid off the trees, and off the insects that had been wetted by it. There was no question of waiting for settled fine weather, as the work had to be done before the expansion of the blossom. Arsenate of lead was combined with the soft-soap wash for aphis and sucker, in order to poison the food of caterpillars. If pests should attack the varieties not sprayed, they will be treated after the fall of the blossom, and in any case varieties subject to scab will be sprayed with lime-sulphur of summer strength.

Results of spraying

One of the most unsatisfactory features of spraying is the difficulty of determining its results, and that difficulty has proved particularly great this season. Even in the cases of Apples most infested, such as those in which five or six out of twenty trusses of blossom were found to contain aphides, and three or four a few suckers, I could not find more than one dead aphis or sucker in fifty trusses examined a day or two days after the spraying. I found more live ones, but very few even of these. The question, then, is whether the pests, killed or weakened by the wash, were washed out of the trusses by heavy rain. It is commonly assumed that aphides are washed off the trees by rain, and particularly by a thunderstorm; but, so far as I know, this is an assumption which has never been actually proved. Some trusses found to be infested by aphides could be labelled, some of them being sprayed and others not sprayed, care being taken to avoid any more thorough spraying than would be given on a large scale. If the insects could be counted beforehand, so much the better. Examination could be made 24 hours after the spraying, results being noted; and again after the next fall of rain, if it occurred soon enough. Rain might hold off too long, and the experiment would then have to be repeated. In noting the results after rain, if any pests were found to have been washed off the trees, it should be noticed whether more were ousted from the sprayed trees than from the others. As to a thunderstorm, there can hardly be any special

effect from it, unless the rainfall happens to be more violent than in an ordinary storm, as it is not at all likely that a specially electrical condition of the atmosphere affects the aphis. A busy fruitgrower can hardly find time for such experiments as are suggested. They should be carried out by the authorities paid out of public funds to undertake research. As matters stand, I do not know whether the expense incurred in spraying has been useful or almost useless. There is too much reason to fear that the arsenate of lead has been all, or nearly all, washed off the trees by rain, and that the caterpillars will be able to go on feeding with impunity. They, like the other pests, were in the trusses of blossom buds and the surrounding leaves. "A Southern Grower." p. 301, 10. 5. 13.

Roses .. .. .. Aphis — Should the pest appear on the leaves, syringe the trees with a mixture of soft soap and sulphur. The sulphur will also check mildew. Caterpillars are particularly numerous this season and unless they are diligently sought for they may do much damage. p. 308, 10. 5. 13.

Hardy Fruit Garden .. Gooseberry caterpillar — If the pest has already taken a hold on the bushes, they should be syringed at once with a good insecticide. Some mixture containing a certain proportion of nicotine will answer the purpose best, it will kill the grub in a few minutes. The trees should be afterwards syringed with clean, soft water. p. 309, 10. 5. 13.

Editorial .. .. Vine weevils — Place freshly tarred paper under the vines, then approach the vines with a lantern in the hand, giving each rod a slight shaking....It is difficult to kill the larvae in the soil for they seem proof against any but the strongest and most dangerous applications. p. 320, 10. 5. 13.

Fruits under glass .. Red spider — The vines will need syringing occasionally with an insecticide to destroy red spider. p. 326, 17. 5. 13.

Hardy Fruit Garden .. Apricot — A small yellow caterpillar is a great pest: this pest should be hand-picked and destroyed. After a thorough search syringe the trees with a weak solution of nicotine. p. 327, 17. 5. 13.

Market Fruit Garden .. Apple sucker — Our trees were sprayed with Buxton lime, and in the case of Warner's King, which I have always found the most susceptible to sucker, I used salt with the lime. The spraying was done just before the flower buds parted from the cluster ready for expansion. p. 332, 17. 5. 13.

Editorial .. .. Apple blossom Bud moth — The trees should have been sprayed with arsenate of lead...as soon as the petals have fallen, spray with 1 lb. of arsenate of lead paste to 25 gallons of water. As

there are some aphides in the trusses add 2 lb. of soft soap to the 25 gallons of wash. p. 336, 17. 5. 13.

Editorial .. .. Spray in winter with a wash of 3 lbs. soft soap, 5 gallons water, and 1 pint of paraffin thoroughly mixed. p. 336, 17. 5. 13.
Spruce fir
'Spruce gall'

Hardy Fruit Garden .. Black and green aphides will soon make an appearance on the ends of the shoots and should be destroyed by syringing with insecticide. Leaves that are infested with caterpillars or (? of) the Pear moth, should be gathered and burned. p. 367, 31. 5. 13.
Pear trees on walls

Editorial .. .. To destroy aphis, it is best to fumigate with a nicotine preparation. For red spider, the leaves may be sponged with a little soapy water—half an ounce of soft soap to one gallon of water—mixed with half a pound of flowers of sulphur and kept stirred. Or flowers of sulphur may be applied dry with the Malbec bellows. p. 375, 31. 5. 13.
Aphis and red spider on vines

Roses .. .. .. Syringe roses with an insecticide at least once a week to keep aphis in check. p. 383, 7. 6. 13.
The flower garden

Fruits under glass .. The trees should be syringed frequently with an insecticide. p. 383, 7. 6. 13.
Red spider

Public parks and gardens The Goat moth (*Cossus ligniperda*) is far more common over the London area than is generally supposed, and this may also be said of the Wood Leopard moth (*Zeuzera æsculi*), both of which attack the Elm, Poplar, Ash and Oak. The larvae of both moths, which are deposited on the bark of the tree in July or August, tunnel into the wood and do much damage to the timber as well as the health of the tree. Placing cyanide of potassium in the hole and closing the aperture is the best method of destroying the caterpillar, though we have used gas tar in a similar way with good results. Dislodging the caterpillar by means of a bent wire has been successfully carried out. Lime trees all over London are attacked by the caterpillar of the Lime Looper moth (*Hybernia defolaria*), while the Thorn fly, an Aphis, attacks whole hedges of the Hawthorn as well as specimens standing singly. Sponging with tobacco water is to be recommended for the latter, and for the Lime trees caterpillar bands of any sticky substance painted around the stems will prevent the insects ascending to the branches. Red spider (*Tetranychus telarius*) is another formidable insect pest that not infrequently attacks the leaves of several species of hardwooded trees, and is often the cause of death of the Ivy, particularly when grown as a ground carpet. The leaves turn a rusty-brown colour, crumple
Tree pests in London

up, and finally fall off, the whole plant dying in consequence. Large areas of the Ivy used for ground work in various parks and gardens of London have been killed outright of late years. Spraying with soft soap will prevent the insect from spreading. Though the Beech is by no means a common tree in London, yet of the few specimens to be found, many are attacked by *Cryptococcus fagi*, which is alarmingly on the increase in this country. Paraffin or petroleum emulsion will destroy the insect, and scrubbing the bark with a rough brush and soft soap is an excellent remedy. Wholesale destruction to the leaves of the Spindle tree and other species of Euonymus is yearly occasioned in some of the London parks by the caterpillar of the small Ermine moth, myriads of the caterpillars appearing on the foliage during summer. So rapidly does this insect increase, and so verocious is its appetite, that a shrub will be completely stripped of its foliage in two or three days. Spraying with XL All Insecticide or petroleum emulsion is the best remedy. Where Oak trees are found in London, the Oak-leaf Roller moth (*Tortrix viridana*) is usually present about the beginning of June. It is a very destructive insect, and attacks not only the leaves, but buds and inflorescences, and usually works from the top of the tree downwards. Where only a single or few Oaks are attacked spraying may be resorted to, but hardly any remedial measure can be adopted in a clump or plantation of the tree. Starlings, rooks and other birds destroy vast numbers of this pest, and should be encouraged. By "Superintendent." pp. 400, 401, 14. 6. 13.

Apples and plums .. Spraying lime-wash just before the buds approach the bursting stage in dry weather.

An important object lesson Very striking evidence as to the advantage of spraying Apples and Plums with lime-wash, as thick as it can be got through the spraying machines, was obtained in Mr Hooper's orchards. In one portion of the farm all the Apple and Plum trees had been sprayed with this wash, nothing being added to the lime, except water, while they were left unsprayed in the rest of it. The lime-sprayed Apples and Plums were free from the aphis blight, while those not sprayed were very badly infested. If memory serves, the contrast applies also to Apple sucker infestation. At any rate, a mere glance was sufficient to allow any one to see it in relation to the aphis blight, and growers elsewhere to

whom this striking case was named said that they had seen similar results from lime spraying. Mr Hooper's explanation is that the lime coats over the eggs of the pests, and extracts moisture from them, thus destroying their vitality. Lime-wash must be strained before it is put into a spraying machine, and it is important to do the work only in dry weather, and to cover every twig. If rain occurs before the stuff has dried thoroughly on the trees, the lime is easily washed off; but it sticks on well after being dried. In the case under notice the spraying was done as soon as there was any sign of an attack by birds upon Plum buds. Apart from this attack, however, just before the buds approach the bursting stage is probably the best time to apply the lime-wash. "Southern Grower." p. 414, 21. 6. 13.

Flower Garden. Aphides on chrysanthemums — It is wise to spray with some insecticide of moderate strength. p. 436, 28. 6. 13.

Hardy Fruit Garden .. Wall trees — Red spider, syringe the foliage constantly with water, to which has been added a little quassia extract.

If the cherries are infested with black fly, the affected shoots should be cut away and the trees syringed with an insecticide. After each application a syringing of clean water should follow. This method will be found to be a great improvement on the old plan of applying tobacco powder. p. 437, 28. 6. 13.

Editorial .. .. Cabbage root maggot — Soft soap, one quart, in one gallon of boiling water. Add one pint crude carbolic acid and dilute with 30 times its bulk of water. Syringe the ground around the attacked plants. p. 444, 28. 6. 13.

The spruce aphis .. — Spraying with paraffin emulsion is recommended. Soft soap and quassia extract may also be tried. p. 5, 5. 7. 13.

Hardy Fruit Garden .. Black aphis — If there are bad infestations the growths most affected should be cut off and burned and the tree syringed afterwards, first with an insecticide, then with clean water. p. 9, 5. 7. 13.

Editorial .. .. Conifer coccus — Next winter drench the trees thoroughly with soft soap and paraffin emulsion. p. 20, 5. 7. 13.

Fruits under glass .. Peaches — The foliage should be syringed thoroughly or washed by means of the garden engine two or three times a week. This will cleanse the leaves of insect pests. p. 29, 12. 7. 13.

Editorial .. .. Celery fly — Pinch the maggots in the leaves and remove the leaves. ...Afterwards you can make the plants distasteful to the flies by syringing them with quassia extract, or you may scatter soot, lime, etc. p. 60, 19. 7. 13.

Editorial .. .. Ripersia on palm roots	Remove the plants and spray the exposed roots and soil with carbon bi-sulphide, using a small glass spraying apparatus. The process must be repeated. Another plan is to have holes in the soil and pour one teaspoonful of the carbon bi-sulphide in each hole.	p. 76, 26. 7. 13.
Editorial. Rose leaves	'Extract of Quassia.'	p. 76, 26. 7. 13.

Board of Agriculture Leaflets.

Mangold fly	paraffin	1 gallon	Formula 1.
	soft soap	½ lb.	
	water	10 gallons	
Onion fly	paraffin	3 pints	Formula 2
	soft soap	½ lb.	
	water	7 gallons	
Surface caterpillars	soot and lime		
	Paris green	1 lb.	
	water	50 gallons	
Celery fly	paraffin	1 quart	Formula 3.
	soft soap	½ lb.	
	water	10 gallons	
	carbolic acid	1 pint	
	soft soap	½ lb.	
	water	10 gallons	
Carrot fly	paraffin	2 gallons	Formula 4.
	soft soap	½ lb.	
	water	60 gallons	
Red spider	sulphur		
	paraffin	7 gallons	Formula 5.
	soft soap	6 lbs.	
	liver of sulphur	2½ lbs.	
	water	100 gallons	
	sulphate of iron	8 ozs.	Formula 6.
	caustic lime	4 ozs.	
	paraffin (solar)	16 to 24 ozs.	
	water	10 gallons	
	liver of sulphur mixed with quassia wash		
Asparagus beetle	Paris green	1 lb.	
	water	200 gallons	
	arsenate of lead	3 ozs.	
	treacle	1 lb.	
	water	10 to 12 gallons	
Thrips	pyrethrum	1 oz.	
	soft soap	1 oz.	
	water	2 gallons	
Hop aphis	soft soap	4 to 10 lbs.	
	water	100 gallons	
	or with 6 lbs. quassia chips		

Aphides	soft soap	6 to 10 lbs.	
	water	100 gallons	
	or with quassia 6–8 lbs. added		
	paraffin	2 gallons	On dormant trees (Woburn formula).
	soft soap	1½ lbs.	
	caustic soda	6 lbs.	
	water	28 gallons	
Cabbage fly	paraffin	1 cupfull	
	sand	1 pailfull	
Black currant gall mite	lime	1 lb.	
	sulphur	1 lb.	
	water	20 gallons	
Vine weevils	soft soap	1 quart	
	crude carbolic	1 pint	
	water	30 gallons	
Winter moth	Paris green	1 lb.	
	water	200 to 250 gallons	
	arsenate of lead paste	2 lbs.	
	water	50 gallons	
Gooseberry sawfly	hellebore	1 oz.	
	flour	2 ozs.	
	water	3 gallons	
	Paris green paste	½ oz.	
	water	10 gallons	
Apple sucker	paraffin	2 gallons	Formula 7.
	soft soap	½ lb.	
	water	11 gallons	
	carbolic acid	2 to 3 gallons	
	soft soap	6 lbs.	
	water	100 gallons	
Woolly aphis (Winter washes)	caustic soda	10 lbs.	
	carbonate of potash	10 lbs.	
	soft soap	2 or 3 lbs.	
	water	100 gallons	
	soft soap	1½ lbs.	Woburn formula.
	paraffin	2 gallons	
	caustic soda	6 lbs.	
	water	28 gallons	

Speaking generally, the following are methods in fairly general use:

1. Lead arseniate or Paris green for caterpillars.

2. Soft soap and quassia for hop aphis; soft soap alone or with quassia extract for aphides generally.

3. Sulphur in some form for red spider.

4. Washes containing free caustic alkali for cleaning tree trunks in winter.

5. Paraffin in very weak emulsion with soft soap or paraffin stirred up in water for garden pests.

6. Lime, salt and sulphur in vague proportions for apple sucker, etc.
7. Lime washing for winter use.
8. Nicotine as a general panacea for all pests, as a stomach poison for caterpillars, as a contact poison for apple sucker, aphis, etc.

It will be admitted probably that these insecticides have come into use on purely empirical lines; the use of arseniates has probably come from human toxicology, and a very exhaustive inquiry into the action of some mineral compounds in India[1] has not produced anything more poisonous; it is probably a question of the *form* of arsenic to be used. But what has governed the choice of insecticides that do not act on the internal organs, but those acting from without? I think none but tradition and purely empirical practice, with experience in large scale experiments as a deciding factor.

Is experience on a large scale experiment of much real use? It is in some cases, such as mussel scale, where the insect is one-brooded; I doubt if it is much use in a many brooded or migrating insect, such as an aphis. The factors that control the increase of aphis are many and it would require very careful examination of the conditions to say that the spraying had done the real work, or that the actual nature of the insecticide had been the deciding factor. Suppose a grower of plums sprays for the Leaf Curling Aphis in June; a week after he looks for aphis and finds none; he thinks it is the spraying, whereas it is the migration of the aphis from the plums that has produced the absence.

It is worth while thinking for a moment how these insecticides act; what actually happens when paraffin emulsion is applied; where does the paraffin go to, what tissue does it affect, how does it work? A Board of Agriculture Leaflet states "The presence of the soft soap causes the wash to touch the aphis, and as it dries the thin layer of soft soap clogs the breathing pores and kills the insect" (Hop aphis). Did the author of this statement really know this, or was it simply the generally accepted statement? If so, why do most growers add quassia, and why does quassia kill aphis? what does quassia actually do? I do not think actually that anyone can tell us what the quassia extract does, and I believe that we shall get much better insecticides when we know how it is that these things kill. What is it that happens? If we know that, can we not devise insecticides that make this happen, not that happen to kill?

[1] Lefroy and Finlow. Memoirs of the Agricultural Dept., India. *Entomology*, vol. IV. no. 5.

If we did, it is likely that some of them would be much the same as before, since the sum total of human experience, however got, brings one near the truth. Experience tells us that paraffin kills; it does not tell us how; but knowing how is not going to tell us not to use it. Paraffin will still kill; only ultimately out of knowing why, we shall know whether paraffin itself is the best or whether there is something better not yet tried.

In considering the question of insecticides there are a number of points and I would like to suggest two:

1. *Spreading over and wetting the plant.* In many cases it is necessary to spread over or wet the plant in order that the substance contained in suspension or in solution should be spread over the leaf.

If a leaf is sprayed with mercury, the mercury would not spread over or wet it; the mercury would draw into drops and run off.

If it is sprayed with water, the water might spread and it might not 'wet'; on a cabbage leaf it would not spread or wet, on others it might.

If you sprayed it with pure paraffin it would spread over and wet all the plant and the paraffin would 'creep.' Why this difference of behaviour? It is partly due to two things: the surface tension of the liquid, high in mercury, middling in water, low in paraffin; the question of the inter-solubility of the liquid of some constituent of the surface of the leaf, *e.g.* the wax on the cabbage leaf, being totally insoluble in the water and causing the water to roll off at once.

To spread, therefore, one must presumably have a low surface tension, and to wet also have a wax solvent or a liquid that will be absorbed by or dissolve the outer coat. Now leaving the question of a leaf with its broad surface, take the case of a bud or a curled leaf: here still more the surface tension question is apparent as the liquid might need to penetrate the curled leaf and act by capillarity. I will quote a case here I had need to go into carefully: we had a disease on indigo in which the plant curls into a compact knot at the tip; in this lives a *Psylla*. It was a question of finding an insecticide that would wet and penetrate. We found by experiment that some insecticides penetrated better than others. We found that they varied according to the concentration, and we eventually found one that penetrated so well as to go right in.

Dr Leather, the Imperial Agricultural Chemist, very kindly measured surface tensions for me and this last had the lowest. It was an "oleic" acid soap at 1 lb. in 12 gallons of water. It was the

best soap we got and it was better than rosin compound, oil emulsions, soda solutions and other things. An oil emulsion in ·8 per cent. soap solution has a higher tension than the soap solution. We tested 'penetration' by dipping curled heads of the plants, then cutting them open and seeing what had happened.

Now in this case it was purely one of getting a commercial product of low enough surface tension to wet and penetrate the curled plant. We had to think afterwards of what we could put in to kill the insect. A similar case exactly will be described to you in the paper by Mr P. R. Awati.

Apart from the mere surface tension, what of the different behaviour of a liquid on an ordinary leaf or on a cabbage leaf: is there a reaction between the liquid and the surface depending on the latter? I am not a physicist and cannot say, but I believe there is and, so far as I understand it, I explain it below. But you can get round this in some cases by adding to the liquid a solvent of the wax (if any) in the plant. For instance, a cabbage leaf behaves very differently to a liquid containing a solvent of its wax than it does to the liquid without; for the solvent dissolving the wax eliminates the wetting question since the wax is there already, and it becomes therefore a question of 'spreading.' Spreading power, even more than wetting, depends on low surface tension and we may, I think, distinguish "spreading of a liquid over a surface it never wets" and wetting due to the liquid actually entering into solution with a substance on the leaf surface. You may attain 'spreading' of the liquid by either method but not wetting.

I am indebted to Dr Vaughan-Cornish for a reference to Clark-Maxwell's *Theory of Heat*, in which surface tension is discussed. I have endeavoured to extract the gist of the physics of surface tension so far as it refers to this problem.

The spreading power of a liquid on a solid depends in this way on surface tension:

When a solid body (the leaf) is in contact with two fluids (air, wash) then if the tension of the surface separating the solid from the second fluid (wash) exceeds the sum of the tensions of the other two surfaces, the second fluid will gather itself into a drop and the first fluid spread over the surface, *i.e.*

$$\text{If} \quad \text{S.T. of Wash and Solid} > \begin{matrix}\text{S.T. of Wash and Air} \\ + \text{ Air and Solid,}\end{matrix}$$

then the Wash goes into a drop.

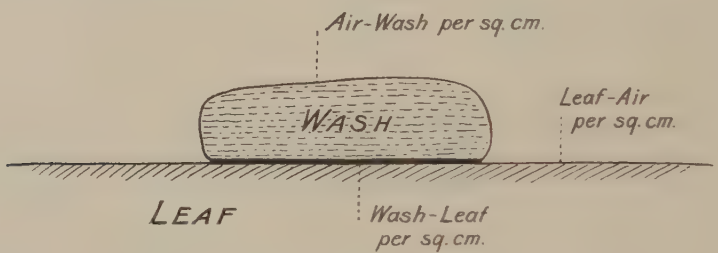
If the reverse, the Wash spreads over the whole surface and will wet the Solid.

Assuming then that the surface tension of the air and the solid (the leaf) is always the same, and that the surface tensions of Wash-Solid and Wash-Air vary proportionately according to the nature of the wash, then clearly the measure of the surface tension of Wash-Air is an indication to us of the wetting power, and the lower this is the greater the chance of wetting.

The equation is

$$\text{Wash-Solid} < \begin{matrix}\text{Wash-Air} \\ + \text{ Air-Solid,}\end{matrix}$$

clearly the lower the two Wash surface tensions, the more likely are we to get the one we want.



The Air and Water surface tensions of these liquids are:

	Air	Water
Water	8·253	—
Petroleum	3·233	2·834
Mercury	55·03	42·58

I have not the surface tensions of any of these with a leaf surface so I cannot work out an equation, but the above figures show why, for instance, mercury and petroleum and water behave differently as regards leaf surfaces.

It will be noticed that it is not only the wash-air surface tension that counts, but the wash-solid and the solid-air. The difference between the wetting power of water on a cabbage and on an apple leaf is due to the difference in surface tension to air and wash between the wax on the cabbage leaf and the substance on the apple leaf. In the first case

$$\text{Wash-Wax} > \begin{matrix}\text{Wash-Air} \\ \text{Wax-Air}\end{matrix}$$

and no wetting occurs by the wash.

In the second case

$$\text{Wash-Apple leaf} < \begin{matrix}\text{Wash-Air} \\ \text{Apple leaf-Air}\end{matrix}$$

and wetting occurs.

Therefore, the nature of the actual substance on the surface of the leaf determines whether the wash will wet or not.

If then we knew the surface tensions of

plant-air,
plant-wash,
wash-air,

we could always tell if the wash would roll off or not. So for the insect: if we knew the surface tension of

aphis-air,
aphis-wash,
wash-air,

we should know if our wash would wet the aphis or not. As we do not know these, and as our plant-air, or aphis-air, remains a constant, we strive to make the wash a practical success by getting one in which wash-air (measurable) and therefore wash-plant is as low as possible. One imagines that, had insecticides received attention from chemists and physicists, the constants surface tension of plant-air, plant-wash, wash-air could be looked up, as also the more complex surface tensions of emulsions. When drops of oil float in an emulsion they affect the surface tension of the emulsion in relation to air and plant.

2. The next point is this: how do these insecticides act; must the liquid spread over the insect, must they 'wet' it, and, if so, then how do they act?

There are, I think, three points:

(1) Mere spreading over mechanically.
(2) Wetting with spreading.
(3) Toxic action after wetting.

(1) In the first case I take such actions as lime wash, which spread over mechanically and never wet; the action may be due to mechanical causes solely, probably suffocation.

(2) Wetting, including spreading, means the insecticide is in physical contact with the body. What does this really mean? Does it mean that the head, the segments, the antennae and legs are wetted, or that only parts are, or that there is a film of the liquid lying over the whole insect but not actually in contact, say, with the under surface?

I take it to mean that the insect is actually in contact with the insecticide all over without any air-film between. It means, for instance, that the liquid is in contact with the spiracles.

(3) Means that *it also has a toxic action.* Now assuming that we have an insecticide that spreads, that wets and that penetrates to the insect, what happens then we do not know.

With a view to getting some accurate ideas I made a large series of experiments with meal-worms with these results:

1. No action is got by applying any liquid for a short time to the skin, but many act at once if applied to a single spiracle.

2. Interference with the mechanical functions of at least five pairs of spiracles is necessary to produce any symptoms due solely to mechanical interference.

3. Closing all spiracles produces a condition we may call 'rigour,' in which a liquid will enter the spiracles.

4. It is impossible to get a liquid to enter one spiracle unless this condition is produced.

5. Dipping a meal-worm in a liquid produces the condition in which the liquid enters. We can therefore compare the effects of liquids by this means.

6. Of liquids tested the following results were got:

Killed all	*Killed some*	*Killed none*
Clove oil	Quinoline	Picric acid in water
Xylol	Carbolic acid	Alcohol 70 %
Turpentine	Formol 4 %	Nicotine 1 % aq.
Nitro-benzene	Pyridine	Acetone
Chloroform	Acetic acid	Ether
Amyl acetate	Eucalyptus oil	Chloral hydrate aq.
Cymene	Methyl salicylate	Water
Pseudocumine	Aniline	
	Acetic ester	

Now results with meal-worms are not of much direct use and we must, for the moment, eliminate the peculiar 'rigour' results. But they show us, I think, that a much greater range of liquids than are generally used have a toxic action and that we must attach far more weight to the details of the structure of the spiracles and tracheal system.

It would look even as if only through the spiracles could one reach most insects with an insecticide, and that the insecticide that did not actually fill the spiracles was not acting. I suggest this is why contact poisons fail against large insects as a general rule: the liquid may wet

but does not wet the whole insect and so the spiracles, or part of them, are free.

The positions of the spiracles, for instance in a Scale Insect, a Psylla, an Aleurodid, and an Aphid, are very different indeed. Their structure is different, they have different arrangements for closing them. In Psylla and Aleurodes the adult is very readily killed with insecticides, partly probably because it has very inefficient spiracles and requires much air, whereas the young form is harder to kill because it has a very efficient closing and protecting apparatus and requires less air.

What I suggest is that the way to tackle the question is first to investigate the tracheal system of the insect. Second, to investigate the wetting action of the insecticide on the plant, unless the insect is fully exposed. Thirdly, to investigate the wetting action on the insect, or the dissolving of its waxes or coating; and fourthly the actual toxic ingredient that would be added to the insecticide to act on the insect when it reached it.

Are any of these factors really taken into account in the recommending of insecticides? I think they should be, and there is here a large field for research.

In preparing this paper I have not attempted in any way to summarise the present practice of insecticides outside this country; this would be a very large subject, complicated by the now enormous use of insecticides sold under fancy names by firms who may or may not have any real knowledge of entomology. But I would like to include abstracts of some papers published in America.

"How contact insecticides kill," G. D. Shafer (*Michigan Sta. Tech. Bul.* XI, pp. 65, pls. 2, figs. 7). This bulletin consists of two parts, the first of which (pp. 8–53) deals with the effects of certain gases and insecticides upon the activity and respiration of insects, and the second (pp. 53–64) with some properties of lime-sulphur wash that make it effective in killing scale insects, especially San Jose scale. Abstracts of these have been previously noted (*E.S.R.*, XXV, p. 665). The investigations conducted and here reported in detail have been summarised by the author in the following general conclusions:

"Usually contact insecticides do not depend upon one property or means alone for their effectiveness, yet as a rule some one property is chiefly concerned. Alkaline washes, corrosive sublimate solution, and other fluids, which are capable either of dissolving or of precipitating certain constituents of insect tissues, are able to penetrate the chitin of insects into the tissues slowly. The weaker the surface tension of the fluid, apparently, and the thinner the chitin with which it is in contact the more rapid the penetration. Gases and vapors may penetrate the chitin of insects, especially through the tracheae into the tissues far more rapidly than liquids.

"It is through absorption into the insect tissues of the volatile portions of kerosene, gasoline, creolin, pyrethrum and such contact insecticides that they mainly become effective agents against insects. Vapors from these insecticides enter the tissues and become effective long before the liquids as such have time to penetrate the chitin. Kerosene, miscible oils, etc., are able to enter the spiracles and tracheae of insects even when a 'closing apparatus' is present; but the comparatively rapid influence which such insecticides exert does not come from the plugging of the tracheae alone.

"The general effects of vapors from gasoline, kerosene, carbon disulphid, creolin, and the rest upon insects are very similar to the effects of the vapor of ether. The nervous system seems to be especially affected. Small amounts of such vapors produce, at first, more or less excitement; then a period of uncertain movements; and finally in larger amounts anesthesia or narcosis. The respiratory activity is usually increased until after the insects become deeply affected, and it is then depressed.

"Certain gases and vapors (*e.g.*, sulphur dioxid, ammonia and hydrocyanic acid gas) when present in respired air continue to be absorbed by insects while they are alive. For the most part, these gases are not given off when the insects are exposed to fresh air, but become rather firmly fixed within the tissues.

"Insect tissues quickly become saturated with any certain percentage of the vapor of carbon disulphid, carbon dioxid, kerosene, gasoline, or similar vapor and no more (at that percentage) is taken up. Then when the insects are exposed to pure air, practically all of such vapors or gases are given off from the tissues again—but not quite as readily as they were absorbed.

"Starvation, serious mechanical injury, and ammonia gas were all found to reduce the value of the respiratory quotient below the value given when healthy strong insects are breathing pure air.

"The vapors of gasoline, carbon disulphid, kerosene and To-bak-ine (*i.e.* nicotin), when present in sufficient amounts to bring the insects near death, cause the value of the respiratory ratio to rise above the value given by healthy, strong insects breathing pure air—*i.e.*, these vapors depress the activity of oxygen absorption more than they do the carbon dioxid excreting activity. The insects tried could continue to give off small amounts of carbon dioxid when no oxygen was present to be taken up, as when they were kept in tested nitrogen, hydrogen, or carbon dioxid.

"The evidence gathered seems to indicate that the vapors of gasoline, kerosene, carbon disulphid and the like, after absorption into the insect body, become mainly effective through some tendency their presence exerts to prevent oxygen absorption by the tissues.

"Lime-sulphur is a special rather than a general contact insecticide. Its strong, persistent reducing power, and its ability to soften the wax about the margin of a scale insect like the San Jose scale, are the important properties that make it efficient as a scalecide." *Expt. Stat. Record*, 1912.

"A contribution to our knowledge of insecticides," C. T. McClintock, E. M. Houghton and H. C. Hamilton (*Rpt. Mich. Acad. Sci.* x (1908), pp. 197–208, pl. 1, reprint).... "The work reported in this paper has to do with contact insecticides only....

"The insecticidal, germicidal, and toxic values (for higher animals) have little or no correlation. It is possible to determine the relative strength or value of insecticides

by immersing test insects in definite strengths of the insecticide, and noting the time required to produce death. The common bedbug (*Cimex lectularis*) appears to be the most satisfactory test insect. As yet the mode of action, the way in which the contact insecticides cause the death of the insects, has not been determined. Apparently, the fewer the number of spiracles, the smaller their size, and the better they are guarded by hairs or valves, the more resistant is the insect to the contact insecticides.

"Chemical standardisation of this class of insecticides is with our present knowledge impossible. With two substances, having essentially the same composition, the insecticidal values may vary enormously. Even the same substance, prepared with what are apparently unimportant chemical variations, gives widely different insecticidal values."

Relative efficiency of contact insecticides.

Kohlentear	125
As_2O_3 soap sol.	50
Terpentin säure	40
Schwafel säure	15
Nikotin	15
Leinol seife	5
KCN	5
Kresyl säure, seifen lösung ..	2·5
Karbol säure, seifen lösung ..	2·0
Morphin sulphat	2·0
Karbol säure, H_2O	1·0
$HgCl_2$	0·5
HgI	0·5
Formaldehyd	0·4
Alkohol	0·05

"A further contribution to our knowledge of insecticides," C. T. McClintock, H. C. Hamilton and F. B. Lowe (*Jour. Amer. Pub. Health Assoc.*, 1 (1911), No. 4, pp. 227–238, pl. 1): "It is possible to standardise substances which are subject to sophistication or deterioration by comparing the efficient dilution of their vapours with that of a product of known purity. This is particularly applicable to solutions of nicotin and to powdered chrysanthemum flowers. As yet there is nothing from which to conclude what action the vapours have on the insects. If it were merely irrative, formaldehyde would be valuable and the vapours of the burning insect powder without value. If the action were similar to anesthesia, chloroform should have been of greater value. If the action were purely that of poisoning one would have expected the highly poisonous hydrocyanic-acid gas to be of exceptional value for all species of insects."

These show that the way in which contact poisons act is not by any means clear, and that a great deal of research in insect physiology is required before we do know anything about it.

In conclusion, I wish to emphasise the practical bearing of this subject. I may have shed no light on it, but I do think that we owe it

to horticulturists to investigate these problems. The wetting of leaves and plant-buds is one point; the wetting or penetration of insects is another; the toxic action on insects is a third, and the last is to combine the three together in efficient insecticides that really do kill the insect every time and that cause a direct mortality of 100 per cent. In seeking an insecticide for woolly aphis, I would first seek a solvent of its wax. This is easy, but it is far from easy for instance with beech Coccus. In seeking an insecticide for apple sucker we first sought one that would wet apple buds. For mussel scale I would seek either a solvent of the secretionary part of the scale, or a liquid that would penetrate under the scale. These are protected insects, but what about naked insects such as bugs, aphides and the like; each has to be tackled individually. So too for stomach poisons. We know that we want to wet the leaves uniformily. Does lead arseniate and water wet well? I think not. In using lead chromate we add 25 % soft soap and 1·5 % of gelatine, simply to secure wetting; it is worth while as we use less liquid to get good even wetting and no dripping. What will wet one plant's leaf may not wet another. We know that for cabbages, for instance, but it is a factor seldom taken into account except with cabbages.

I hope I have shown that there is a field for research in this question. I wish we could get a satisfactory basis of reason on which to proceed, and not have to rely on empirical methods which really are not always successful. And I am inclined to think that in England too much reliance is placed on the tar and water principle to the detriment of the estimation in which applied Entomology is held by horticulturists and fruit growers.

THE COMPOSITION OF THE COFFEE BERRY AND ITS RELATION TO THE MANURING OF A COFFEE ESTATE.

By RUDOLPH D. ANSTEAD, M.A.,

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During the past five years I have been studying in Southern India the manurial problem as it affects coffee from a chemical standpoint with the object of trying to obtain some hint not only as to the best proportions of plant food to give this crop, but also at what time of year the plant food is best applied.

The first step was to investigate the composition of the mulch obtained from the shade trees and the coffee itself and to determine its manurial value. The result of our experiments was to show that under well-established mixed shade some four tons air-dry weight of mulch is accumulated per acre each year, and that this mulch contained 108 lbs. of nitrogen, 223 lbs. of calcium oxide, 36 lbs. of phosphoric anhydride, and 118 lbs. of potassic oxide per acre. From this it was concluded that the amount and composition of the mulch obtained annually from the shade trees was an important factor and should be taken into account when drawing up a manurial programme over a series of years, and also that it was quite possible that the coffee, where a heavy mulch was established as happens on many estates, was apt to receive an unbalanced ratio of plant food, the nitrogen being in excess with the result that leaf growth was encouraged at the expense of fruit.

Attention was next devoted to the chemical composition of the coffee berry itself. When an analysis of parchment coffee, or coffee berries, is examined it is at once noticed that potash is a dominant factor among the mineral constituents. This being so it is only logical to suppose that a fertiliser containing a preponderance of potash should help the coffee tree to ripen up and hold its crop, and the question at once presents itself as to when this potash should be applied. Do the coffee berries need it from the very beginning of their development,

as soon as they have set and the blossom has fallen, or do they need it only towards the end of their development? The same question also applies to the nitrogen and phosphoric acid. It seemed to us that if an answer could be found to these questions it would have a profound practical bearing upon coffee manuring practice.

During 1912 analyses were made of coffee berries each month from July to December throughout their period of development from the time they were quite small to the time when they were ripe and ready to pick and pulp. As it was found impossible owing to the press of other work to make a large number of analyses of different samples for comparison, and to get an average uniformity was attempted by taking a careful sample from a large number of berries of similar development carefully picked in the field.

The results of the analyses are shown in the following tables:

Analyses of Fresh Coffee Berries from July to January.

——	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
Moisture	87·13	84·45	80·75	71·54	66·06	65·77	66·62
*Organic matter ...	11·96	14·67	18·18	26·93	32·05	32·48	31·58
Ash — Silica	0·04	0·01	0·03	0·02	0·02	0·04	0·05
Ash — Phos. acid ...	0·08	0·07	0·09	0·16	0·15	0·12	0·12
Ash — Potash	0·37	0·43	0·49	0·77	0·93	0·88	0·96
Ash — Lime	0·04	0·02	0·02	0·02	0·04	0·02	0·02
Ash — Other mineral matter	0·38	0·35	0·44	0·56	0·75	0·69	0·65
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00
*Containing nitrogen	0·30	0·38	0·24	0·50	0·61	0·67	0·66

Analyses of the Ash of Coffee Berries from July to January.

——	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.
Silica	4·48	1·48	2·84	1·23	1·11	2·47	3·03
Phos. acid	8·48	8·04	8·20	8·40	7·87	6·56	6·83
Potash	40·31	48·38	45·78	50·30	49·40	50·10	53·19
Lime	4·27	2·04	1·89	1·17	1·89	1·23	1·14
Other mineral matter	42·46	40·06	41·29	38·90	39·73	39·64	35·81
Total ...	100·00	100·00	100·00	100·00	100·00	100·00	100·00

The first table shows the actual composition of the fresh berries as regards the constituents named, while the second table shows the composition of the ash, that is the mineral part in each sample, it being chiefly this mineral matter with which we are concerned. In July the berries were very small and it required 72 of them to weigh one ounce. In December the berries were fully developed but still green or only just yellowing. At this stage the beans are developed and if pulped yield good coffee. In practice the berries are allowed to ripen and develop sugar, turning red in the process, in order to facilitate pulping and subsequent fermentation of the pulp adhering to the beans which enables the latter to be washed clean, the fermentation process having no effect upon the quality of the actual coffee bean. The last column in the tables is the analysis of the ripe berries as picked for pulping.

These analyses show that there is a markedly steady increase of potash content throughout the period of growth, and from this it is concluded that potash in an available form is needed all the time. The phosphoric acid content appears to be a constant quantity at first with a maximum about October after which it declines, hence it seems likely that this constituent is needed in an available form chiefly in the beginning of the season. The nitrogen content increases steadily throughout the period of growth and keeps pace with the increase of organic matter.

On these results a series of manurial experiments have been based and are now being carried out, but I should like here to especially call attention to the moisture content of the berries during their growth and development.

From July to December when the berries are fully developed in size there is a rapid and regular decrease in the amount of moisture in the berries. It falls from 87·13 % in July to 71·54 % in October and 65·77 % in December.

This confirms Mr H. B. Guppy's results. In his recent book *Studies in Seeds and Fruits*, he states that immature fruits contain more water than mature fruits, and that in the living plant or its part the decrease in the percentage of water is due to the fact that during the building up processes involved in growth the solids increase more rapidly than the liquid constituents.

During the ripening process, however, the moisture content increases by nearly one per cent., and this would appear to be a critical stage in the history of the berry.

Much more work is needed upon this point, but it is significant that

every year a certain amount of crop falls off and that in certain cases, on certain types of soil, the trees fail to hold their crop late in the season. This last year, 1913, was a dry one with also a large crop, and it was most noticeable that many of the berries failed to complete the last stage and would not ripen, but had to be picked and pulped while still hard and yellow instead of soft and red. The moisture factor has undoubtedly some bearing upon phenomena such as these, and it is possible that they can be controlled by methods of cultivation and the application of fertilisers which tend to increase the root area or conserve the soil moisture. The results so far obtained suggest at any rate interesting side lines of research, such as the above and the study of the physical condition of different types of coffee soils and their moisture content at different times of the year in the relation to the ability of the coffee grown on them to hold and ripen up a big crop.

THE LIFE-HISTORY AND HABITS OF THE GREENHOUSE WHITE FLY[1] (*ALEYRODES VAPORARIORUM* WESTD.).

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(*Imperial College of Science and Technology, South Kensington.*)

(With 56 Text-figures.)

THIS insect is commonly known as the "Greenhouse White Fly," from its general occurrence on greenhouse plants. It is classified as follows:

Family, *Aleyrodidae* ("Mealy wings"). Wings white, not transparent; antennae with seven segments; both sexes winged; tarsus with two segments.

Sub-order, *Phytophthires.* Antennae long and simple; tarsi with one or two segments.

Homoptera. Fore wings not thickened at the base; head bent over to touch the coxae.

Order, *Rhynchota* (Hemiptera). The mouth parts form a jointed beak (rostrum), bent under the thorax; two pairs of wings.

Aleyrodes vaporariorum has a wide range of food plants, and prefers potatoes, and such greenhouse plants as tomato, cucumber, melon, heliotrope, lantana, salvia. Although the flies and larvae are very small, they occur in such immense numbers that the plants become impoverished, and the quantity and quality of such fruit as tomatoes and cucumbers decreased. The whole of the under-side of the leaves is often completely covered with the scale-like larvae and pupae. They produce a large amount of excreta (honeydew), which falls on to the

[1] A paper on insecticidal treatment for White Fly has been delayed, pending the result of further work: Mr Hargreaves' departure for the United States prevented the second part of this paper, dealing with the treatment of White Fly, being completed. It will appear in an early number.

leaves below, inviting the prolific growth of fungi which ruin plants used for ornamental purposes. The adults prefer the young leaves for oviposition, and gradually ascend as the plant grows. Hence there will be green eggs on the newest leaves; a little lower, brown eggs; lower still the first stage larvae will predominate; below these the second stage larvae; and so on. Finally, on the oldest leaves, adults will be emerging. Occasionally eggs are laid on the stalks, flowers, and upper leaf surface; but they are generally laid in circles on the under-side, if the leaves are not very hairy and the insects undisturbed. The circle of eggs is made in a very ingenious way. The insect inserts its stylets into the leaf tissue and, using that point as centre and its body as radius, revolves as each egg is deposited. Hairiness of the leaves prevents this turning and the eggs are then scattered. The eggs are stalked, the stalk being short and partly embedded in the tissue of the leaf and arranged perpendicular to the leaf surface. They are green

Fig. 1. Egg.

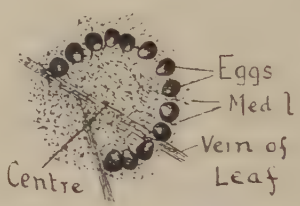

Fig. 2. Circle of eggs.

when first deposited and covered with the wax ("meal") produced by the adult, as also is the portion of leaf in the vicinity of the eggs. The circles of eggs are generally incomplete, with a diameter of about 1·5 mm., and I have not seen more than 15 eggs in one ring. (Length of stalk, 0·02 mm., total length of egg, 0·24 mm., greatest breadth, 0·70 mm.)

After two to four days (according to temperature, as I kept the humidity fairly constant) the eggs begin to darken in colour, turning from the original yellowish green to brown and finally to black. When nearing the time of hatching, which is about ten days after deposition, the meal drops off, leaving the egg smooth and shiny. The larva is visible inside, and its two eyes appear as bright red spots shining through the egg case near its free end. When about to hatch, the egg moves slightly from side to side, and two surfaces may now be distinguished: a convex, corresponding to the dorsal, and a concave, corresponding to the ventral surface of the larva. Hatching occurs ten to thirteen days after deposition. A crack appears near the free end of the egg on

its concave side (Fig. 3), and the anterior end of the larva emerges. The insect bends towards the leaf until it can get a hold, the legs, as they emerge, being used to push the egg-case free of the larva. The process

Fig. 3.

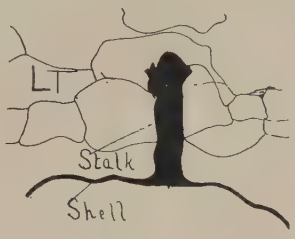

Fig. 4. Stalk of egg embedded in leaf.

is further assisted by flexure and alternate contraction and expansion of the abdomen. The empty egg-case is left standing on the leaf, collapsed.

Fig. 5. First instar.

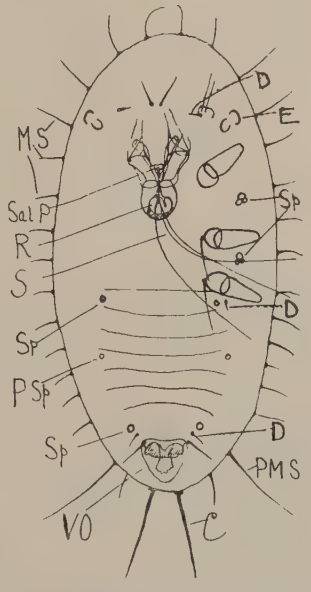

Fig. 6. First instar, from stained mount.

In an instance I observed, the time which elapsed from the appearance of the crack to the complete freedom of the larva was seventeen minutes.

Instar I (Fig. 5). The newly-emerged larva is very pale greenish yellow in colour, and the eyes, being bright red, are very obvious,

because of the contrast. Each eye is completely divided into two parts, each of which appears to consist of a single ommatidium. The larva is 0·29 mm. long, transparent, with a pair of dark yellow masses (present in all stages) in the abdomen, generally in the three or four anterior segments, but sometimes extending into the thorax. This pair of yellow masses is the mycetoma, or pseudovitellus. The segmentation of the abdomen is not distinct until a few minutes after emergence, when the chitin has hardened. There are six abdominal segments, but no differentiation in the thorax. The body margin has a series of spines (Fig. 6), fifteen pairs of which would seem to be segmentally arranged, since they are so arranged in the abdomen. Between the posterior two pairs is a pair of much longer spines; and posterior to all of these are the very long cerci (Fig. 7).

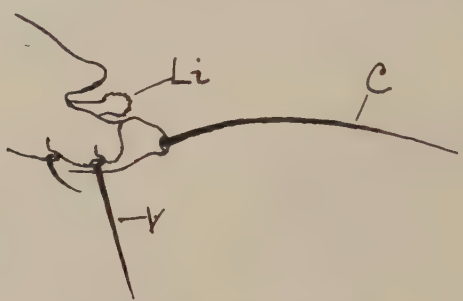

Fig. 7. Lateral view of hind end.

This larva is active for about three days, during which time it wanders about the under-surface of the leaf. It thus differs from some other species in which the larva simply gets clear of the egg before settling. Previous to settling down, or at about this time, the spaces between the marginal spines become filled in with wax formed by marginal wax glands.

The larva prefers a position alongside one of the leaf veins, and since the site it occupies is retained by the later instars, which are sedentary, the choice of this first larva is important. The waxy fringe is much wider in this stage than in the succeeding ones, and it gradually narrows in the succession. Behind the sixth abdominal segment, dorsally, is the vasiform orifice, the consideration of which I leave till later. Legs and antennae are functional during active life, and are well developed compared with those of the three later stages.

Mouth parts. There is a very short rostrum situated between the anterior legs. Two pairs of stylets correspond to the maxillae and

mandibles of other insects. The mandibles are outside (lateral to) the maxillae, which are fused along their length, forming by their union two ducts—a small posterior one for the passage of the saliva from the salivary pump to the leaf, and a larger anterior one for the passage of the food from the leaf. In the dorsal (anterior) wall of the pharynx is the cribriform organ, to which is assigned the function of tasting the food (sap) as it enters the mouth. The arrangement of the mouth-parts is similar in all the stages.

When the larva inserts its stylets into a leaf, in all the cases I have observed (by means of sections of leaves with the larvae *in situ*), the stylets go to the phloem cells of the vascular bundles, which contain

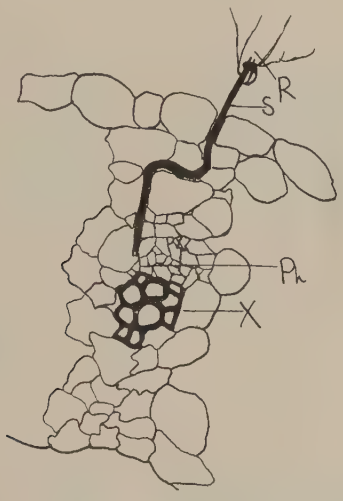

Fig. 8. Larval stylets in the leaf tissue.

proteids and albuminous materials—obviously the most suitable destination (Fig. 8). The entire sucking apparatus (viz. stylets, salivary pump, and chitinous structures in connection with them) is capable of a slight backward-and-forward movement, and this is the case in the next three instars also. As to the stylets themselves, they have a regular cycle of movements (Fig. 9), which is as follows. The mandibles (outer stylets) are thrust forwards (outwards) simultaneously, sliding on the maxillae (inner stylets). Their tips are incurved. They are then withdrawn one at a time, their curved ends scraping against the tips of the united maxillae, as if to bring food towards the latter to be sucked up.

Tracheal system (Fig. 10). This is very simple, there being interconnected dorsal and ventral systems, with very few small branches. This suggests that there may be some respiration through the skin. There are two pairs of thoracic spiracles situated, one pair between the anterior legs, the other between the posterior legs. Also there are two pairs of abdominal spiracles, one pair on the first abdominal segment,

Fig. 9. Cycle of movements of stylets.

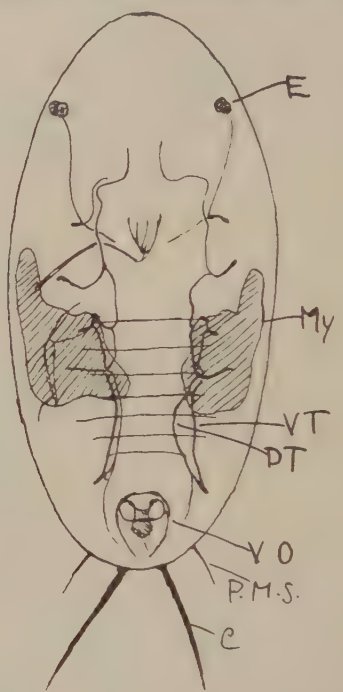

Fig. 10. Dorsal view of a mounted larva.

the other at the sides of the vasiform orifice. All the spiracles are ventral and placed upon elevations.

In preparations to show the tracheal system, there is seen a large vessel which ends suddenly in the fourth abdominal segment, without small branches. It is in connection with the dorsal system (Fig. 10). The larva is very small and the abdominal spiracles are in any case very difficult to observe. It is my belief that this large trachea indicates the presence of a spiracle which I have been unable to demonstrate with certainty. There is certainly an indication of a pair of ventral pores on the fourth abdominal segment.

Legs (Fig. 11). These consist of five segments, homologous, I should say, with the coxa, trochanter, femur, tibia and tarsus, of the legs of other insects. The coxa is small with a large spine on its inner side, and the trochanter comparatively large. The tibia has a large spine on its outer side at about the middle of its length. The tarsus is very small and seems to consist of two segments, the first one bearing a long curved spine externally, the second one terminating in a kind of pad, and possibly being the homologue of the pulvillus or paronychium of the adult, in which case it would not count as one of the actual tarsal segments.

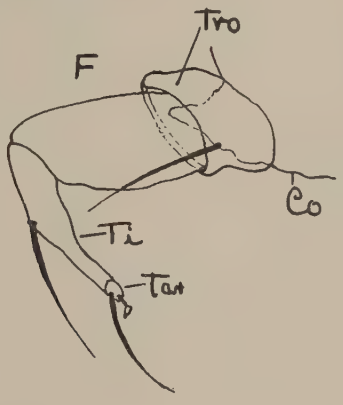

Fig. 11.

Antennae (Fig. 12). Each consists of three segments—the basal one is broad and short; the second is much longer and thinner, with a spine placed near the middle and another at the distal end. The terminal segment is twice the length of the second and terminates in a fine point; there is also a spine at about a quarter of the distance from the distal end.

Vasiform orifice (Figs. 13 and 14). In one of my mounts I was fortunate enough to obtain a side view, and was able to see the hind-gut opening dorsal to the lingula. The lingula is a finger-shaped organ, and just anterior to it, overlying the base, is a plate, the operculum. The anus opens between these.

Spines. In addition to the marginal spines there are five pairs situated as follows: a dorsal short pair over the anterior end of the mouth-parts; a ventral long pair near the middle of the mouth-parts; a ventral long pair beneath the corners of the vasiform orifice; a dorsal

short pair anterior to the vasiform orifice; a dorsal short pair in the first abdominal segment.

Fig. 12. Antenna.

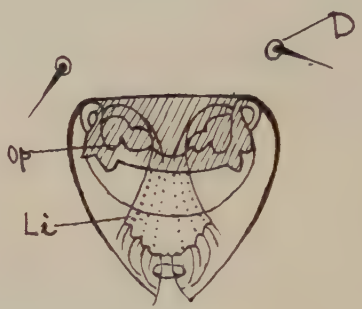

Fig. 13. Dorsal view of vasiform orifice.

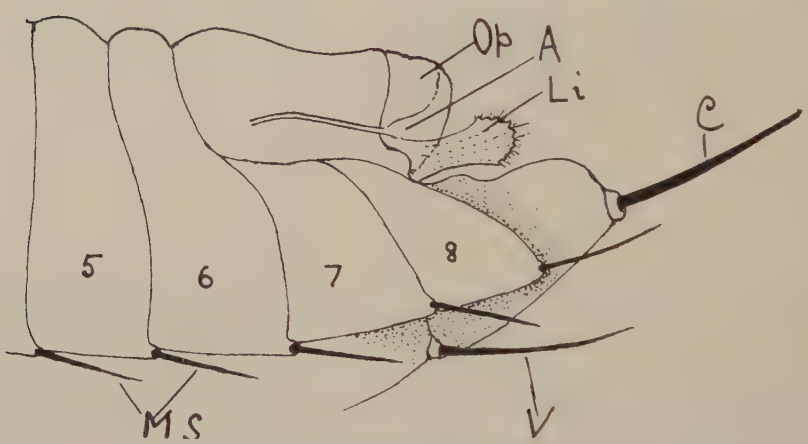

Fig. 14. Lateral view of hind end.

Instar II (Fig. 15).

This (and all stages previous to the imago) emerges from the anterior end of the old larval skin by pushing it off, partly with the aid of its short stumpy legs, but mainly by the flexure and alternate contraction and expansion of the abdomen. The eyes are bright red, and divided. When newly moulted, the larva flattens itself against the leaf, and, being transparent, is very difficult to see. It is a pale greenish-yellow in colour, with a length of from 0·37 to

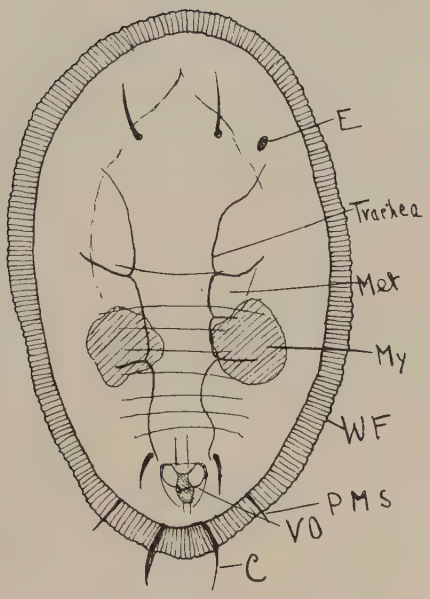

Fig. 15. Second instar.

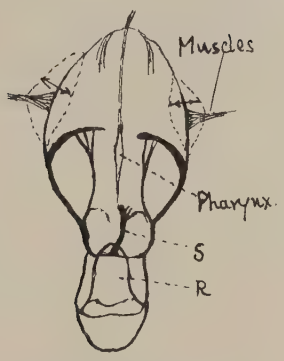

Fig. 16. Mouth-parts of second instar.

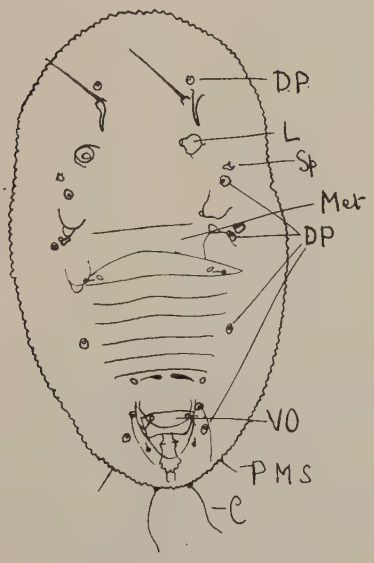

Fig. 17. Second instar.

0·39 mm. A very noticeable feature is the great increase in size (length and breadth), which has taken place at the moult. (This also applies to the two succeeding stages.) The rostrum is more pronounced than in the previous stage (Fig. 16), but the general arrangement of the mouth-parts is the same. This larva generally retains the same position as the last, but I have observed one to move slightly immediately after

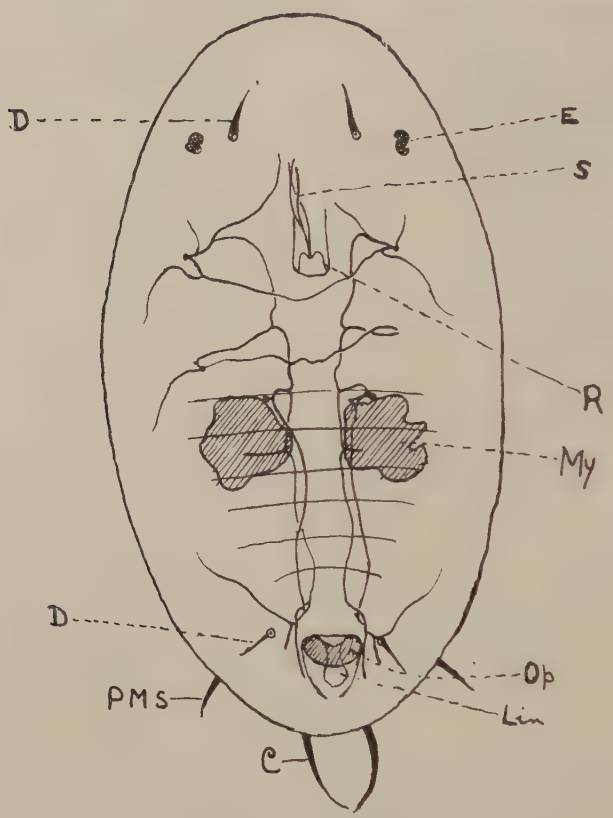

Fig. 18. Second instar.

Fig. 19. Leg of second instar.

emergence. The margin is at first entire except for the cerci and the pair of more anterior spines, both being shorter than in the previous stage. Later, however, a waxy fringe is developed. When this is dissolved, the body margin is seen to have become crenulated (Fig 17). There is a metathoracic and six abdominal segments differentiated.

Tracheal system (Fig. 18). There are dorsal and ventral systems which are connected, and very few small branches are present. There

are two pairs of thoracic spiracles arranged as in the preceding stage, and two pairs of abdominal situated in the first segment and at the sides of the vasiform orifice respectively. A pair of thick tracheae are given off from the dorsal system with evidence of a pair of spiracles, as in the first instar.

Legs (Fig. 19). The legs are much smaller than in the first instar, and they are functionless as ambulatory appendages. Each consists of three segments the homology of which could not be determined with certainty. But it seems probable that the trochanter and tarsus are absent. No spines are present.

Antennae (Fig. 20). The antennae are exceedingly small, and each is made up of two segments, the basal one having a short spine near the middle, and the distal one being covered with very short hairs.

Fig. 20. Antenna of second instar.

Fig. 21. Vasiform orifice and ventral spines.

Spines (Fig. 16). In addition to marginal spines there are—a long dorsal pair over the anterior end of the mouth-parts; a short dorsal pair on the first abdominal segment; a long dorsal pair at the anterior corners of the vasiform orifice; a very short pair at the posterior sides of the vasiform orifice; a short ventral pair beneath the vasiform orifice.

Vasiform Orifice (Fig. 21).

Dorsal pores (Fig. 17). On the dorsal surface are six pairs of pores, which I take to be the openings of the wax glands, the secretion of which covers the general surface of the body. They have a peculiar and characteristic appearance. My preparations were stained with acid fuchsin, and the pores appeared as small dark red rings, surrounded by an area which was of a paler pink colour than the surrounding chitin of the general surface. They are situated as follows: a pair in front of the anterior dorsal spines; a pair each near the thoracic and first abdominal spiracles; a pair in the fourth abdominal segment; a pair at the sides of the vasiform orifice.

Instar III (Fig. 22).

General appearance and habits as in the preceding stage, but larger, with the wax fringe narrower and the marginal spines shorter. It is 0·52 mm. in length, with six abdominal segments, and the metathorax differentiated. Mouth-parts of the same general structure as in the first and second instars.

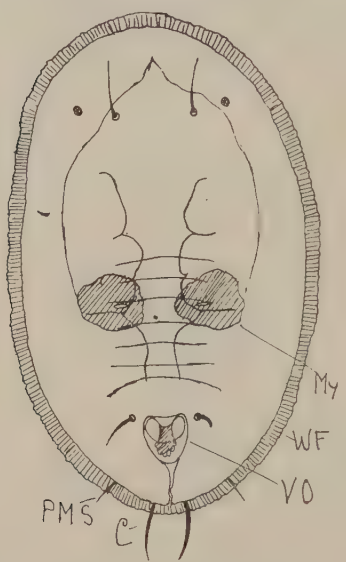

Fig. 22. Third instar.

Fig. 23. Leg.

Fig. 24. Antenna.

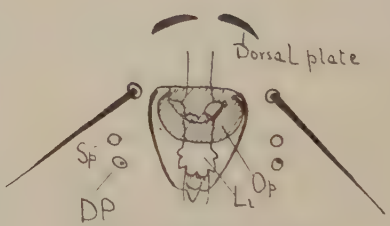

Fig. 25. Vasiform orifice.

Tracheal system. As in the previous stage.

Legs (Fig. 23). The legs are very small, functionless for locomotion, and the structure as in the preceding stage.

Antennae (Fig. 24). Each consists of two segments. The basal one is broad and carries a spine distally; the second is hairy and characteristically hooked.

Vasiform orifice (Fig. 25).

Spines. In addition to marginal, are four pairs arranged—a long dorsal pair over the anterior end of the mouth-parts; a dorsal short pair on the first abdominal segment; a dorsal long pair at the anterior angles of the vasiform orifice; a ventral pair beneath the vasiform orifice.

Dorsal pores. Twelve pairs situated—a pair over the sides of the mouth-parts near the middle line; a pair anterior to the bases of the antennae, and a pair just anterior to them; a pair near each pair of thoracic spiracles; a pair towards the middle of the first abdominal segment; a pair each in the third, fourth, fifth and sixth abdominal

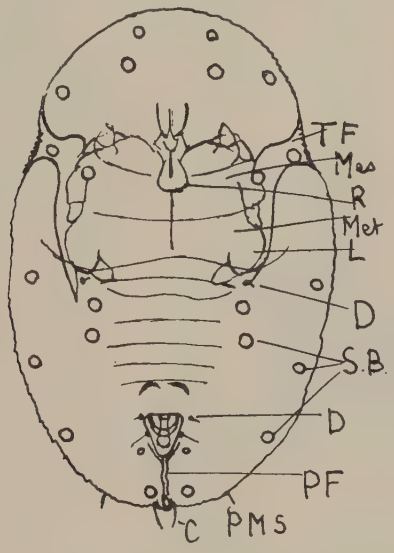

Fig. 26. Fourth instar.

segments; a pair immediately posterior to the sixth abdominal segment; a pair at the sides of the vasiform orifice.

Breathing folds. There is a pair of these folds opening opposite the anterior pair of spiracles, and the lumen of each extends alongside the thorax to the first abdominal segment. I could not find a posterior fold. (See below.)

Instar IV (Fig. 26).

This stage, which may be taken to be the equivalent of the pupal stage of other insects, differs very much in appearance from those preceding. When newly emerged there are eleven pairs of

large round spine-bosses to be seen, situated: seven pairs near the margin, a pair towards the middle line anteriorly, a pair in the thorax, and a pair in each of the third and fourth abdominal segments. Later, the glands at these points give rise to long waxy processes (Figs. 26, 27), the arrangement of which is made use of in systematic work. Like the preceding stages, this instar is at first transparent and a pale greenish-yellow in colour and has small red eyes. The length varies from 0·7 mm. to 0·82 mm. It differs from the others in that much growth in length, breadth and thickness takes place. There are six abdominal and two thoracic segments differentiated. The body margin is at first entire, except for the cerci and posterior spines, which are shorter than those in the preceding stage. Later, waxy processes are developed along the margin generally to the number

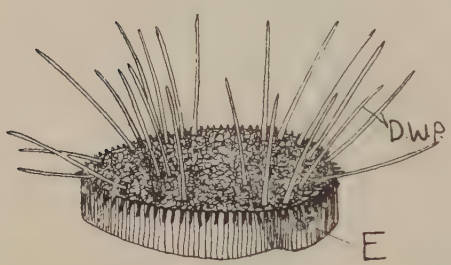

Fig. 27. Fourth instar.

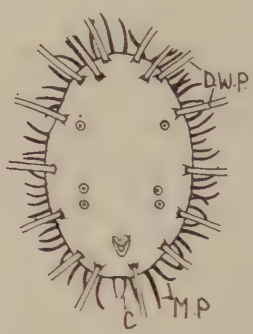

Fig. 28. Fourth instar.

of 38 pairs (Fig. 28). The mouth-parts are similar in structure to those in previous stages.

Tracheal system (Fig. 29). This is much more complicated than in any previous stage, as numerous fine tracheal ramifications are present. There are dorsal and ventral systems, which are in connection.

Spiracles (Fig. 29). There are four pairs of spiracles situated as follows: a pair in the metathorax; a pair of more anterior thoracic; a pair in the first abdominal segment; and a pair at the sides of the vasiform orifice.

Legs (Fig. 30). They are not functional for walking, and consist of three segments, the basal one being very broad. No spines are present.

Antennae (Fig. 31). Each consists of two segments, the distal one terminating in a rather fine point.

Spines. In addition to the marginal and the eleven pairs of long dorsal spines mentioned above, there are: a pair ventral to the vasiform

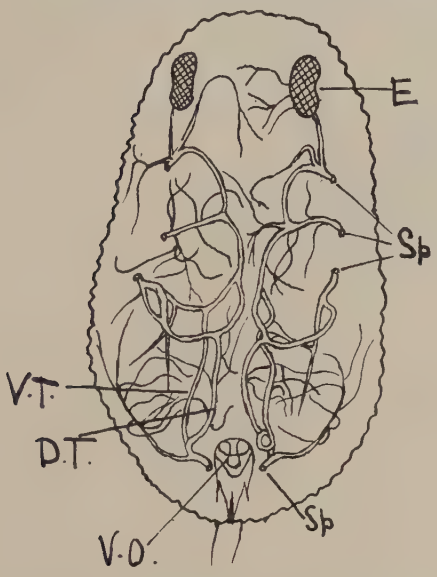

Fig. 29. Fourth instar, tracheal system.

Fig. 30. Leg.

orifice; a dorsal pair at the anterior corners of the vasiform orifice; a dorsal pair in the first abdominal segment; an anterior dorsal short pair over the sides of the mouth-parts.

Fig. 31. Antenna.

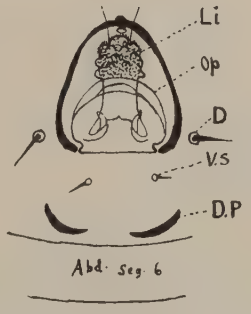

Fig. 32. Vasiform orifice.

Dorsal pores. There are twelve pairs arranged as in the previous stage.

Vasiform orifice (Fig. 32).

Breathing folds (Figs. 26, 33). There is a pair of anterior folds opening ventro-laterally opposite the anterior pair of thoracic spiracles. They are continued alongside the thorax to the first one or two abdominal segments. In the living insect, the passage leading to the exterior

Fig. 33. Ventral view of fourth instar.

appears to be a tube (Fig. 33), the floor of which is formed of wax, so that in specimens which have been treated with a wax solvent, the tubes have become simply grooves (Fig. 26). There is also a posterior fold extending from the middle of the posterior margin to the vasiform

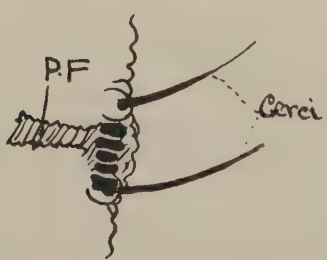

Fig. 34. Opening of posterior fold.

Fig. 35. Opening of thoracic fold.

orifice, which communicates with the posterior spiracles. The character of the margin at the external openings of these folds is peculiar (Figs. 34, 35). Later, the body shrinks away from the cuticle, and the development of the adult organs (eyes, wings, legs, etc.) begins. In sections

at this stage two layers of chitin are to be distinguished, one being that which originally enclosed the fourth instar, the other, inside this, which is destined to be the adult skeleton (Fig. 36). This may be called an

Fig. 36. Section through head of fourth instar.

internal moult. The eyes, from being mere spots in the young pupa, grow enormously to form the compound eyes of the imago. The body grows very much in thickness, becoming box-like in the older pupa (Fig. 27). Also, the antennae, legs and wings may be seen curled up inside the outer case, but outside the body of the insect. As is the case in the preceding stages, the new legs and antennae are formed inside the old ones, and since those of the imago are much longer than those of the pupa, they become folded as they grow. The claws and second tarsal segment easily fill one of the pupal legs (Fig. 37). The

Fig. 37. Adult leg developing in pupa.

wings are outgrowths of the inner layer of chitin, the growth being continuous and gradual and thus differing from that which takes place at successive moults, in steps as it were, in some other insects. So far as I can make out, the wings arise as evaginations, and not as invaginations, which are later evaginated as in insects like the *Lepidoptera*.

Instar V (Fig. 38).

This is the final stage, or imago. It emerges from a T-shaped crack, the crossbar dividing the pupal abdomen from the thorax,

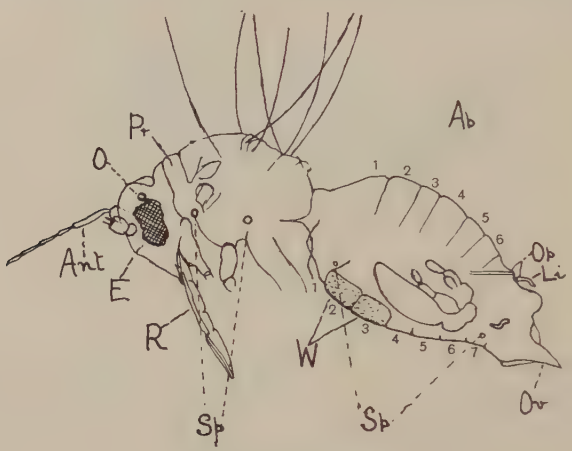

Fig. 38. Adult.

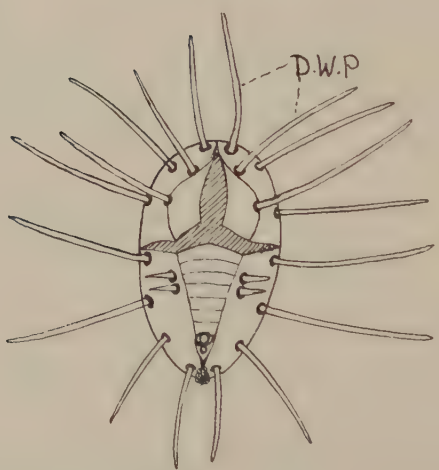

Fig. 39. Empty pupa-case.

the vertical bar being median, and extending from the crossbar to the anterior margin (Fig. 39). The thorax is the first part to emerge; then the head, with the rostrum and antennae, which gradually

straighten out and harden. The legs are then successively drawn out and straightened, and simultaneously with this the rest of the thorax, bearing the wings which are curled up on each side. When the legs have hardened, the insect uses them to push at the pupa case for the extraction of the abdomen. It takes an hour or so for the wings to become straight. The newly emerged imago is quite devoid of any waxy covering, but after some time, its body and wings become covered

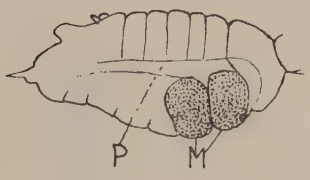

Fig. 40. Adult's abdomen, lateral.

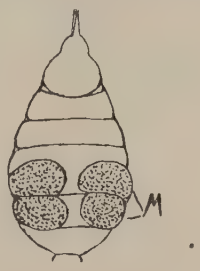

Fig. 41. Adult's abdomen, ventral.

with the white substance (meal, or wax), from which the names "white-fly" and "mealywing" are derived. It varies in length from 0·95 mm. to 1·4 mm. I placed a newly emerged female insect on a slide beneath a coverslip in order, if possible, to observe where the wax was formed. After some time, I found that two pairs of plates were covered with it. These are situated ventro-laterally on the second and third abdominal

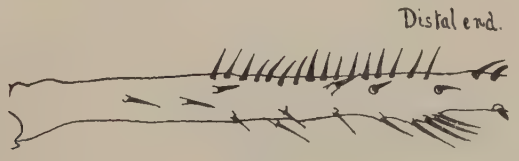

Fig. 42. Part of hind tibia.

segments (Figs. 40, 41). The rest of the body was quite clean. On careful observation of one of the flies while on a leaf, by means of a binocular, I saw that it scraped its abdomen with the tibiae of its hind legs, and then stroked them on its wings, and the remainder of the abdomen. Similarly, it uses its fore-legs for the head and thorax. On the hind tibia is a row of stiff setae, which act as a comb for the transference of the wax (Fig. 42). There are four pairs of wax plates

in the male, situate in the second, third, fourth and fifth abdominal segments. The meal has a peculiar structure, being in the form of spirals or parts of spirals, as if it had been forced through small openings (Fig. 43). In thin sections (Fig. 44), taken through the region of these wax glands, there is seen a single layer of secreting cells with large nuclei, and containing vacuoles from which the wax has been dissolved during preparation. There are also numerous granules which are more numerous towards the exterior. The overlying chitin at first appears to consist of a series of imbricated plates, which effect, however, is due to the presence of small pores, thus giving the chitin that striated appearance.

Fig. 43. Wax threads.

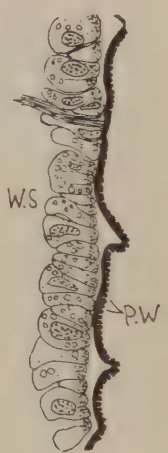

Fig. 44. Section through wax glands.

[In order to determine with certainty the structure of the chitin, special precautions as to lighting, to prevent error from reflection or aberration, were found to be necessary, because of the high magnification required.]

Antennae (Fig. 45). Each antenna consists of two broad segments at the base and five longer and more slender ones. They are placed just in front of the eyes, and show pseudo-segmentation. On each of the third, fifth and seventh segments, situated on their distal ends and on the dorsal (anterior) side, is a circular pit fringed by setae. These are probably olfactory organs. The seventh segment terminates in a fine point. The length of the antenna is 0·36 mm. in the male, and 0·32 mm. in the female.

Rostrum (Figs. 38 and 47). The rostrum is a prominent structure equivalent to the labium of other insects, and consists of three segments, with an imperfect joint again dividing the middle one. On its anterior

Fig. 45. Antenna.

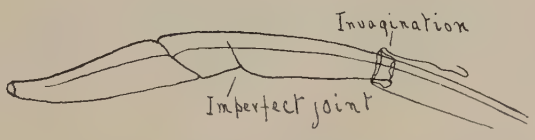

Fig. 46. Rostrum.

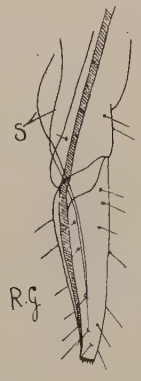

Fig. 47. Rostrum.

surface is a deep groove, extending along its whole length, for the reception of the stylets. The tip is sharply serrated, presumably to enable the insect to get a grip on the leaf surface during insertion of

the stylets. The rostrum may be drawn into the head to such a great extent that the dorsal end of the groove nearly reaches the dorsal wall. It may also be invaginated upon itself like a glove finger (Fig. 46). These arrangements are for the insertion of the stylets, insomuch as the rostrum is longer than the stylets. The portion of stylets outside the plant is completely enclosed in the groove. Hence the rostrum functionally shortens as the stylets are inserted. There is no arrangement in the head for the retraction or expulsion of the stylets themselves. When the insect is not feeding, the stylets are completely enclosed in the rostral groove.

Eyes (Fig. 48). The eyes of the adult are compound, and each is divided externally by an area covered with short hairs, into lower and

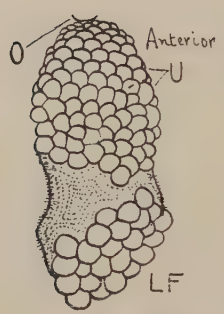

Fig. 48. Eyes.

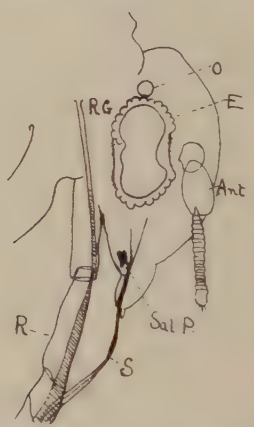

Fig. 49. Side view of head.

upper portions, the upper having smaller facets than the lower. They are very large, and just above each is an ocellus (Fig. 49). The two parts of each eye unite inside the head.

Mouth-parts. The mouth-parts have the same general structure as in the preceding stages, but there is one great difference. In the larvae the stylets may be withdrawn inside the body (Fig. 50), probably into a pouch as in Monophlebus (Coccidae). The mandibles are not fused, either with themselves or with the maxillae, and they may slide upon the latter. They are very slender structures without teeth or serrations.

Segmentation (Figs. 38 and 40). The attachment of the abdomen to the thorax is very narrow. From the dorsal surface small prothoracic and large meso- and meta-thoracic segments are visible. Behind

the six abdominal segments which are to be distinguished dorsally, is a portion in which the vasiform orifice is situated, and which terminates as ovipositors in the female and claspers in the male. There are seven

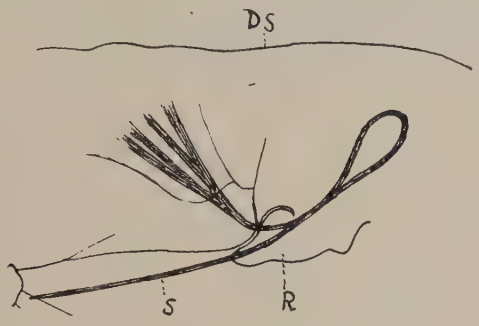

Fig. 50. Stylets of first instar.

abdominal segments visible ventrally. Along each side of the abdomen is a narrow band of thin chitin consisting of the pleura of the segments (Fig. 40).

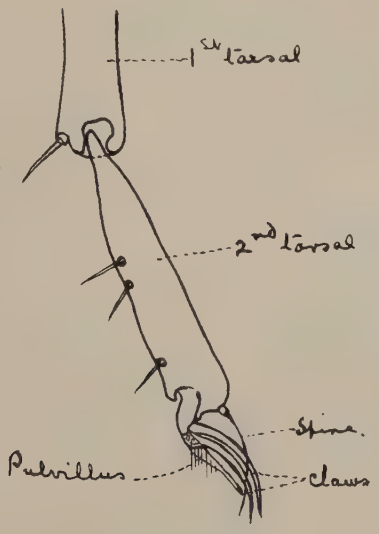

Fig. 51. Tarsus.

Legs. The third pair of legs are the longest and the first the shortest. Each consists of a coxa, trochanter, femur, tibia and a tarsus of two segments. Articulating with the second tarsal segment is a small piece supporting two long curved claws and a median hairy and pointed pulvillus (paronychium) (Fig. 51). There is also a long curved spine

attached independently to the distal end of the second tarsal segment.

Wings (Figs. 52, 53). There are two pairs of wings in both male and female, and the venation of both fore and hind wings is exceedingly simple. There is a series of knob-like structures running round the wing margin, each knob supporting two or three hairs (Fig. 54).

Fig. 52. Fore wing.

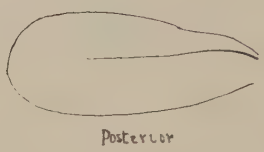

Fig. 53. Hind wing.

Fig. 54. Wing margin.

Tracheal system. The tracheal system is very complicated, as in the pupa, and there are four pairs of spiracles situated as follows: a pair each in the pro- and meta-thorax; a pair on the first abdominal segment placed a little antero-dorsal to the anterior pair of wax plates: a pair on the sides of the vasiform orifice, ventro-laterally.

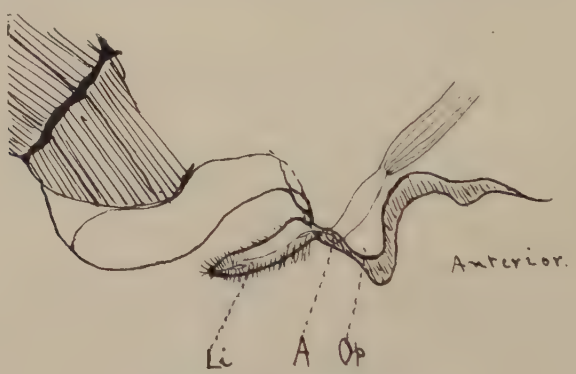

Fig. 55. Vasiform orifice.

[Quaintance[9] in his *Classification of the Aleyrodidae*, states that there are three pairs of thoracic spiracles in the *Aleyrodidae*. Woodworth[4], in *A. citri*, had also described three pairs.]

Vasiform orifice (Fig. 55). The function of this peculiar apparatus

appears to be to get rid of the excreta (honeydew). The lingula moves in a vertical plane, while the operculum moves slightly backwards and forwards. The anus opens on the dorsal surface of the lingula (anterior to it) (Fig. 55). Ventral to the base of the lingula is a cleft, which is presumably to allow the lingula greater freedom of movement. Leading from the base of the lingula near the anus to its tip is a row of rather long setae, and at the tip there is a depression surrounded by them. It would appear that the honeydew is conducted from the anus *via* the row of setae, to the tip of the lingula, in the depression of which it can accumulate and form a globule. It is got rid of by the flicking of the lingula. This flicking is easily seen in the case of the pupa. The honeydew on exposure becomes gradually more and more viscous, and if it were not for the above arrangement the anus would become occluded, and the insect killed. The position of the anus corresponds

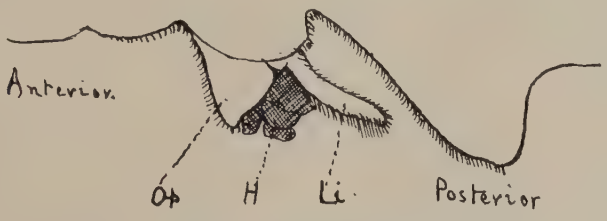

Fig. 56. Vasiform orifice with solidified honeydew.

with the general up-side-down habit of the insect on the under leaf-surface. In some of my preparations there is a mass of clear structureless material filling in the space between the lingula and operculum. This is honeydew which had become so viscous that the insect could not get rid of it (Fig. 56). It may be that the fly had remained in an upright position for some time.

Peal[5], 1903, considered that the lingula secreted the honeydew.

Miss Bernis[6] (*Proc. U.S. Nat. Mus.*, vol. XXVII, p. 475) supports Peal.

Quaintance[9] could not find a definite opening at the tip of the lingula, and states that whether the anus opens at the base or tip, the lingula functions as the supra-anal plate. He homologises the lingula with the supra-anal plate of the Psyllidae, where the anus opens at the tip.

The small numerals refer to the bibliography. 3, 5, 6, 7, 8, and 9 are quoted from Quaintance 1913.

Duration of the various stages.

Egg. Green when laid. Turn brown in two to four days. Hatch in 11 to 14 days from deposition. Mean of 13 cases, 11 days.

Instar 1. Active for two to four days, wandering about the leaf. Duration 10 to 12 days. Mean of 13 cases, 11 days.

10, 10, 10, 10, 11, 11, 11, 11, 11, 12, 12, 12, 12.

Instar 2. Inactive. Duration 14 to 22 days. Mean of ten cases, 17·8 days.

14, 14, 14, 14, 16, 19, 21, 22, 22, 22.

Instar 3. Inactive. Duration five to 36 days. Mean of 20 cases, 18 days.

5, 5, 5, 7, 7, 8, 10, 10, 14, 18, 21, 22, 23, 26, 27, 27, 27, 33, 33, 36.

Instar 4. Inactive. Pupa. Duration 21 to 59 days. Mean of 17 cases, 37 days. The pupa turns slightly yellow before emergence of the imago.

21, 24, 24, 24, 25, 26, 31, 40, 41, 42, 47, 47, 51, 53, 53, 59, 40.

Instar 5. *Imago.* Duration. The longest was 38 days, which was during cold weather.

The weather regulates the duration of all stages, except the egg, which is not affected. Cold weather increases the time, making them live more slowly.

Summary of Duration of the various Instars.

Stage	Cases taken	Mean
Egg	13	13 days
Instar 1	13	11 ,,
,, 2	10	18 (17·8)
,, 3	20	18 ,,
,, 4	17	37 ,,

Life Histories.

Egg laid	Hatch	Moult 1	Moult 2	Moult 3	Imago
16 Oct.	29 Oct.	6 Nov.	23 Nov.	19 Dec.	23 Jan.
18 ,,	30 ,,	9 ,,	27 ,,	24 ,,	27 ,,
16 ,,	28 ,,	4 ,,	25 ,,	22 ,,	23 ,,
16 ,,	30 ,,	10 ,,	1 Dec.	24 ,,	23 ,,
16 ,,	27 ,,	10 ,,	27 Nov.	30 ,,	23 ,,
16 ,,	30 ,,	10 ,,	26 ,,	19 ,,	9 ,,

Parthenogenesis. I placed three females, isolated before complete emergence so as to be absolutely certain that they had not been fertilised, each on a clean plant. From these I obtained ten, thirteen and twenty imagos respectively, all females. From these I got females again, and out of the hundreds of flies which I examined I did not encounter a single male.

Morrill[8] on parthenogenesis in the *Aleyrodidae*, states that unfertilised eggs hatch giving larvae which result in male flies, and suggests that the fertilised eggs will all give rise to females, as in bees. Morrill and Back further established parthenogenesis in *Aleyrodes citri*.

Some General Notes.

Spiracles. There is evidence for the presence of three pairs of abdominal spiracles in the first three instars. In the other two, however, there is not. It might be suggested that this reduction during development is some indication that an ancestor of the *Aleyrodidae* had a pair of spiracles in each abdominal segment. These may possibly be developed in the embryo, all except the remaining three being absorbed before hatching.

Breathing folds. In the case of the instars which are fixed in one place during their existence, viz. the second, third and fourth, they are fixed to the leaf by the waxy fringe. Since the spiracles are ventral, there must be some arrangement for the access of air. This requirement is met by the "breathing folds." On each side of the thorax, opposite the first pair of thoracic spiracles, the ventral body-wall is transversely folded, the fold being continued along the sides of the thorax and part of the abdomen. This allows for the access of air to the thoracic and first abdominal spiracles. The animal forms a floor of wax to these folds, thus converting them into tubes (Fig. 33). The margin at the openings of these differs from the rest (Figs. 34, 35). There is a similar median longitudinal one posteriorly for the access of air to the spiracles on the sides of the vasiform orifice. In the first larva, either the folds are absent, or are too small for observation. But there may be other arrangements in this case, if such are required. In the first place, I have seen a few of the larvae walking about after the formation of the waxy fringe, which suggests that the fringe is not in contact with the leaf. This would obviate the necessity of breathing folds. Also, there is a long spine on the inside of the basal joint of each leg, and a pair of long ones beneath the vasiform orifice. These may function as resting

spines. These long leg-spines are absent in the other stages, and those beneath the vasiform orifice, if present, are short.

When larvae are nearing the moult, they become fat and lose their close contact with the leaves, so that they are then easy to see. The first three instars do not grow in length during their existence, this taking place entirely at the moult; but they grow in thickness (dorso-ventrally). Thus, the length for each of these three instars is constant, and it may, therefore, be used as a criterion of the stage. It varies within 2 μ only. The fourth instar (pupa), however, grows considerably (12 μ) in length, and also very much in thickness (Fig. 27).

The *honeydew* on exposure becomes very viscous, so that any stage which feeds for any considerable time with its dorsal surface upwards, is quite likely to have its anus clogged, as is the case in some of my whole mounts of adults. In these cases the plug of honeydew is situated on the dorsal side of the lingula, thus confirming the dorsal position of the anus with relation to the lingula, which I demonstrated both in a whole mount and by means of sections.

Dorsal pores. On the dorsal surface of the second, third and fourth instars are small pores, those in the abdomen and thorax being segmentally arranged. They are probably pores for the passage to the exterior of wax formed by the underlying cells, the body being covered with it. But it is not a white powder or meal as in the adult.

It may be asked: Why are all the stages generally on the underside of the leaves? The following points require consideration:

(1) The character of the cuticle of the leaf.
(2) Presence of stomata.
(3) Protection from wet.
(4) Phototropism.
(5) Position of the anus and character of excreta.

(1) The cuticle is certainly thinner, and the vascular bundles are nearer the surface, on the underside of the leaf.

(2) In all the sections of larvae *in situ* that I have examined, in no case do the stylets penetrate a stoma.

(3) All the stages have a waxy covering, so that the position as a protection from wet would appear to be a subsidiary matter.

(4) If a leaf with flies on the under-surface is turned over, after a time all the flies migrate to the other side and may lay eggs there. This fact excludes points (1) and (2). If a leaf hangs with its surface in a vertical plane, the females do not show any preference of leaf-surface for oviposition. To catch the flies, I turn a leaf over, and, holding a

specimen tube over a fly, touch it with the edge of the tube. It may behave in two ways: either it flies immediately upwards into the tube, or it simply falls over on its side feigning death. If a fly is touched while the leaf is in the normal position, it does not generally immediately take to flight, but drops for three or four inches, and then flies quickly away from the plant. If a number of the flies are placed in a tube, they all congregate at the upper end. This seems to be an attempt to get into the position with the dorsal surface downwards, and not a result of phototropism. I placed some flies in a tube, and, as usual, they congregated at the upper end. So I covered all the tube except the lower part to exclude the light, and placed a Nernst lamp beneath, so that the light was shining upwards into the darkened tube. It did not, however, cause the flies to come to the bottom of the tube, which indicates that they are not positively phototropic. And their general behaviour points to their not being negatively phototropic.

(5) I consider that the situation of all the stages on the under leaf-surface is correlated with the dorsal position of the anus. The following considerations lead me to this conclusion:

If the insect were dorsal surface upwards

(*a*) it would be unable to get rid of its excreta, which would clog the anus, or, accumulating on the leaf and becoming viscous, would occlude the spiracles,

(*b*) any accumulation of honeydew (excreta) is a very suitable medium for the growth of Fungi,

(*c*) the newly-hatched first larva would become entangled in the viscous excreta which fouled the leaf and would be unable to settle down,

(*d*) the various larvae when moulting would have difficulty in casting off their old skins.

Enemies. Now as to the enemies of the insect. I have not encountered any animal parasites as yet, either of the nymphs or the adult. On one occasion I caught a mite which was holding and devouring a living fly. Spiders also prey on them. On one leaf a spider was discovered surrounded by the remains of half-a-dozen of the flies. Fungi occasionally kill both adults and nymphs.

Methods of eluding predaceous enemies. (1) Escape by dropping, and flight.

(2) Transparency of the larvae is probably a factor in this, as it renders them practically invisible.

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EXPLANATION OF FIGURES.

All figures are drawn at stage level with tube length of 150 mm. Leitz oculars and objectives throughout.

Figs. 10, 15, 17, 18, 22, 46, 49, Oc. 1, Ob. $\frac{1}{6}$.
Figs. 1, 3, 29, 38, Oc. 3, Ob. $\frac{1}{3}$.
Figs. 5, 6, 7, 16, 21, 25, 30, 32, 34, 36, 37, 42, 45, 47, 48, 51, 55, 56, Oc. 3, Ob. $\frac{1}{6}$.
Figs. 4, 8, 11, 12, 13, 14, 19, 20, 23, 24, 31, 43, 44, 50, 54, Oc. 3, Ob. $\frac{1}{12}$ (oil imm.).

The following are reduced:

Figs. 12, 15, 17, 25, 31, 32, 35, 37, 38, 42, 44, 46, 48, 50 to $\frac{2}{3}$.
Figs. 4, 5, 6, 8, 22, 45, 47, 49 to $\frac{1}{2}$.

Fig. 1. Egg.
Fig. 2. Circle of eggs. Note surrounding meal.
Fig. 3. Egg showing crack for emergence of larva.
Fig. 4. Section of egg *in situ* on the leaf.
Fig. 5. Ventral view of living first instar. Note the broad fringe of wax, cerci, legs, antennae, eyes, stylets, mycetoma, segmentation.
Fig. 6. Ventral view of stained preparation to show spiracles, mouth-parts, eyes, marginal and other spines.
Fig. 7. Lateral view of posterior end of abdomen to show the length of the cerci.
Fig. 8. Larval stylets in the leaf tissues.
Fig. 9. Cycle of movements of stylets.
Fig. 10. Dorsal view showing tracheal system. Note dorsal and ventral parts.
Fig. 11. Leg of first instar from the outer side. Note the basal spine on the inner side.
Fig. 12. Antenna.
Fig. 13. Dorsal view of vasiform orifice.
Fig. 14. Lateral view of posterior end of abdomen of first instar showing vasiform orifice. Note the anus opening between the lingula and operculum, and marginal spines.
Fig. 15. Dorsal view living second instar. Note wax fringe, cerci, and pair of posterior marginal spines.
Fig. 16. Mouth-parts of second instar. Note peculiar folded rostrum, short length of protruding stylets, dilated pharynx with the dilator muscles and their direction of action (indicated by arrows).

Fig. 17. Dorsal view second instar, showing spiracles, dorsal pores, crenulated margin, etc.
Fig. 18. Ventral view showing tracheal system, mycetoma, eyes.
Fig. 19. Leg. Note spine on basal segment and hairy terminal one.
Fig. 20. Antenna.
Fig. 21. Ventral view vasiform orifice and adjacent spines.
Fig. 22. Dorsal view living third instar, to show the narrow wax fringe, cerci, eyes, mycetoma, marginal spines.
Fig. 23. Leg.
Fig. 24. Antenna. Note spine on basal segment and the hairs on the hooked terminal segment.
Fig. 25. Dorsal view vasiform orifice, with adjacent spines, spiracles, dorsal pores.
Fig. 26. Ventral view mounted pupa showing breathing folds, legs, spine bases, segmentation, short cerci and marginal spines.
Fig. 27. Dorso-lateral view of late pupa to show box-like form, dorsal and marginal wax processes. The eye of the imago inside is seen through the wall.
Fig. 28. Dorsal view living pupa to show the marginal wax processes and cerci.
Fig. 29. Dorsal view showing tracheal system and spiracles. Note the small ramifications.
Fig. 30. Leg.
Fig. 31. Antenna. Note the pointed end.
Fig. 32. Dorsal view vasiform orifice and adjacent spines.
Fig. 33. Ventral view living pupa showing tubular entrances to breathing folds.
Fig. 34. Opening of posterior breathing fold. Note cerci and character of margin.
Fig. 35. Opening of thoracic fold. Note position of spiracle, and margin.
Fig. 36. Section through region of head of late pupa showing the two layers of chitin.
Fig. 37. Portion of partially emerged adult showing relation of adult leg to that of pupa.
Fig. 38. General outline of adult female. Only coxae of legs and bases of wings indicated. Note position of spiracles, antennae, eye, ocellus, wax plates, rostrum, ovipositors, position of vasiform orifice with hind gut; small prothoracic segment.
Fig. 39. Dorsal view of empty pupa case. Note T-shaped crack through which adult has emerged and the 11 pairs of long dorsal wax processes.
Fig. 40. Lateral view abdomen of female showing position of wax plates and the pleura of the segments.
Fig. 41. Ventral view of same.
Fig. 42. Proximal two-thirds of hind tibia. Note comb of spines on inner posterior side.
Fig. 43. Some of the meal. Note spiral form.
Fig. 44. Section through wax glands. Note character of gland cells and overlying chitin. (Section passes through the juncture of two segments.)
Fig. 45. Antenna. Note pseudosegmentation, sense organs, terminal point.
Fig. 46. Rostrum, showing invagination at end of first segment, and the imperfect joint in the second.
Fig. 47. Side view part of rostrum. Note groove and the toothed tip.
Fig. 48. Adult eye. Upper facets are smaller than the lower, with intervening short hairs.
Fig. 49. Side view of head. Note position of salivary pump and stylets, and the portion of rostral groove in the head.
Fig. 50. Side view of mouth-parts of first instar, to show loop of stylets inside body, and the rostrum.
Fig. 51. Claws and second tarsal segment. Note the small piece with which the claws and pulvillus articulate, and the long curved spine attached to the tarsal segment.

Fig. 52. Ventral view forewing. Note simple venation.
Fig. 53. Hind wing.
Fig. 54. Portion of wing margin.
Fig. 55. Lateral and slightly dorsal view of vasiform orifice. Note anus opening dorsal to the lingula, the row of hairs on the lingula and the depression at its tip.
Fig. 56. Vasiform orifice, with solidified honeydew between the lingula and operculum.

Abbreviations used in figures.

Anus	*A.*	Pupal chitin	*P.C.*
Abdomen	*Ab.*	Posterior breathing fold	*P.F.*
Antenna	*Ant.*	Phloem	*Ph.*
Cercus	*C.*	Posterior marginal spine	*P.M.S.*
Claws	*Cl.*	Prothorax	*Pr.*
Coxa	*Co.*	Probable spiracle	*P.Sp.*
Dorsal spine	*D.*	Pulvillus	*Pul.*
Dorsal wax pore	*D.P.*	Pores for wax	*P.W.*
Dorsal surface	*D.S.*	Rostrum	*R.*
Dorsal tracheal system	*D.T.*	Rostral groove	*R.G.*
Dorsal wax processes	*D.W.P.*	Stylets	*S.*
Eye	*E.*	Salivary pump	*Sal. P.*
Femur	*F.*	Base of spine	*S.B.*
Future adult chitin	*F.A.C.*	Spiracle	*Sp.*
Granules	*G.*	Sensory pit	*S.P.*
Hardened honeydew	*H.*	Thorax	*T.*
Leg	*L.*	Tarsus	*Tar.*
Lower facets	*L.F.*	Thoracic breathing fold	*T.F.*
Lingula	*Li.*	Tibia	*Ti*
Leaf tissue	*L.T.*	Trochanter	*Tr.*
Meal	*M.*	Upper facets	*U.*
Mandible	*Mand.*	Ventral spine	*V.*
Maxilla	*Max.*	Vacuole	*Vac.*
Mesothorax	*Mes.*	Vascular bundle	*V.B.*
Metathorax	*Met.*	Vasiform orifice	*V.O.*
Marginal wax processes	*M.P.*	Ventral surface	*V.S.*
Marginal spines	*M.S.*	Ventral tracheal system	*V.T.*
Mycetoma	*My.*	Wax plates	*W.*
Ocellus	*O.*	Wax fringe	*W.F.*
Operculum	*Op.*	Wax secreting cells	*W.S.*
Ovipositor	*Ov.*	Xylem	*X.*
Pleura	*P.*		

INFECTION AND IMMUNITY STUDIES ON THE APPLE AND PEAR SCAB FUNGI (*VENTURIA INAEQUALIS* AND *V. PIRINA*).

By S. P. WILTSHIRE, B.Sc.

(With Plates XIX—XXII.)

The diseases of apple and pear caused by *Venturia inaequalis* (Cke.) and *V. pirina* (Aderh.) exhibit many interesting phenomena with regard to the resistance and susceptibility of varieties of the hosts. The investigations described in this paper were commenced with the object of discovering the method by which these fungi attack their hosts, in order finally to investigate the features concerning the question of relative immunity. Notwithstanding the rather considerable amount of work which has been done on these diseases—especially the extensive reports of the Agricultural Stations of the United States—little definite knowledge is available, either as to the minute details of infection or the power of resistance of attacked varieties. The recent paper of Wallace[1] contains an exhaustive review of previous work on these diseases: here therefore it is unnecessary to do more than make a brief reference to those points which concern the subjects dealt with in this paper.

The previous work which has been done with regard to the infection of *Venturia* is limited to comparatively few papers. Aderhold's work[2] on these fungi is by far the most important that has ever been published, and to him we are indebted for most of our knowledge of them. In his description of the germ tube he states that it broadens slightly at the point of entrance, which is usually directly over the junction of two or more epidermal cells, and bores directly through it. He mentions that the appressoria are frequently surrounded by a zone of mucilaginous material, but his figures show no signs of the collar which is described below, neither do they indicate the characteristic sub-cuticular mycelium.

[1] Wallace, *Scab Disease of Apples.* Cornell Univ. Agric. Exp. Station, Bull. 335.

[2] Aderhold, R., *Die Fusicladien unserer Obstbäume Land. Jahrb.* xxv, 875–914.

Fischer[1] states that *Venturia* cannot attack a completely uninjured fruit without previous injury to the epidermis. The attack is dependent on the weather, cold nights followed by warm days cause injury to the epidermis. Small cracks arise which can be seen with the aid of a lens, and he explains the conditions favouring infection, as due to the injuries of the cuticle brought about by them.

Voges[2] notes the presence of a "gelatinous envelope" round the appressoria which he suggests are functionary in attachment of the fungus.

Wallace (*loc. cit.*), by boiling up the leaf with caustic potash and thus releasing the cuticle, gathered that the germ tube of an ascospore bores its way directly through the cuticle and continues to grow between it and the epidermis. His figure, which, as far as the writer is aware, is the only one published of the entrance of the germ tube into the host, shows the hypha growing through a crack without the formation of an appressorium and without showing any difference between superficial and sub-cuticular mycelium.

For investigation of the problems of disease resistance connected with any pathological fungus, it is important first of all to determine the actual details of infection by the fungus. Having ascertained the facts of infection, knowledge as to the fate of the fungus after penetration into the tissues of the host is required. The work described in this paper deals primarily with those two subjects. In the case of the disease under investigation, a detailed study of the germination of the spores of *V. inaequalis* and *V. pirina*, the method of penetration into the hosts and the fate of the infecting hyphae was made. The methods of investigation adopted, the results and their bearing upon the above questions are described in turn below.

Methods. The germination of the conidia was examined by the method of drop cultures, conidia being obtained both from pure cultures of the fungi on artificial media and from affected leaves and fruits of apple and pear. The same sources served for a supply of conidia for the inoculation experiments. The inoculations were carried out on cut shoots and fruits under bell jars or on shoots which were enclosed in lamp chimneys held in position by clamps on the trees. The atmosphere was kept saturated with water vapour, and the inoculations were kept moist by means of addition of sterilised water from time to time.

[1] Fischer, *Pflanzenkrankheiten*, XIX, 432–434.

[2] Voges, *Zeitschr. Pflanzenkrankheiten* XX, 385–393.

These very artificial conditions were rendered necessary by the peculiar and special conditions under which the fungus infects the host and even under these, apparently the most favourable, infection is by no means always successful. There must remain, therefore, some slight possibility that the results obtained are simply pathological, but since the growth of the mature mycelium in nature is in many ways similar to that of the germ tube in infection, it is thought that this possibility is not very great.

Methods. Examination of inoculations was carried out by the ordinary method of serial sections, the fixatives mostly employed being chromacetic and acetic alcohol, with fuchsin and Licht Grün, and iron haematoxylin as stains. The course of infection was also watched from surface view from permanent preparations made as follows: inoculated portions were fixed in acetic alcohol for about half an hour, then washed and decolorised by absolute alcohol and finally mounted in Gilson's mounting medium, which is not so refractive as Canada balsam.

Germination. The conidia of *V. inaequalis* and *V. pirina* germinate readily in water, most of them showing a germ tube of considerable size after 24 hours, although some take a much longer time. The conidia are easily wetted, and their specific gravity is so heavy (or immediately becomes so on moistening) that on immersion in a drop of water they almost immediately sink to the bottom of it, where some change takes place, so that the conidium becomes attached to the surface on which it is resting. The comparative difficulty with which conidia about to germinate are washed from the slide on which they have rested suggests a definite attacking envelope, but although indications of an outer gelatinous layer have been seen under the microscope they are in all probability optical illusions, for similar indications are found with conidia of other fungi. In nature the germinating spore must after a short time experience desiccation and other changes due to the weather, but it is an extremely important point with regard to the beginnings of infection, that notwithstanding subsequent drying up germination can only be initiated after complete immersion in water for some time—a fact originally discovered by Aderhold, but perhaps hardly fully appreciated by the few more recent workers. It seems indeed rather curious that in an atmosphere saturated with aqueous vapour a spore will not germinate; and, as will be seen later, the correct appreciation of this fact, which has been repeatedly confirmed by the author, is of importance in understanding some of the characteristics exhibited by these fungi. Immersion in

water for a sufficiently long time having once initiated the first stages of germination, subsequent periods of desiccation seem to help rather than hinder the growth of the fungus. The appearance of the germ tube in the two species is characteristic, for in *V. inaequalis* it is rather a continuation of the spore, being formed by the more pointed end growing out as the germ tube; whilst in the case of the *V. pirina* it is sharply defined, arising as a lateral growth near to one end of the spore.

In a hanging drop, the germ tube continues to grow out as a long thin colourless hypha, but on the leaf desiccation soon brings the germ tube in contact with the cuticle and this immediately brings about the formation of an appressorium, the stimulus of contact, shown by Aderhold, causing the germ tube to swell up and at the same time to be closely applied to the cuticle. Some substance is excreted round it so that a flange-like structure is formed round the end of the germ tube, fixing it firmly to the cuticle (see Fig. 1). The changes in shape of the fungal hypha and the exact method by which the flange was formed could not be definitely followed, but the latter seemed to arise as an excretion from the fungal hyphae, no part of the cuticle being involved. At first the flat portion of the flange, which is usually very thin, especially at the edges is colourless; but it soon becomes brown and can readily be seen under the microscope. These "collars" or flanges are much more prominent in some cases than in others, apparently depending upon the state of health of the spore and the conditions of growth of the fungus. The nucleus can usually be seen to be very evident in the appressoria denoting probably great metabolic activity in this region. The formation of the appressorium is not limited to the germ tube, as the tip of any growing hypha may respond to the stimulus, although there is no evidence that the mature mycelium is capable of doing so. If after the formation of the appressorium, the spore is still kept immersed in water, the appressorium begins to put out a hypha from its upper surface, and later its appearance may suggest that it was a lateral outgrowth from the mature hypha. The germ tube generally forms only one appressorium, normally at a short distance from the spore, but sometimes it branches and even develops a short superficial mycelium producing five or six appressoria.

Aderhold and many other workers have noted that the germ tubes frequently swell up into the appressoria over the junctions of the epidermal cells, especially where three or more cells meet. Very careful examination of inoculations in superficial view has been made

and there is apparently a tendency for appressoria to be formed at the place recorded. Further details on this point are referred to later.

Penetration. A point of great importance in infection is that only young leaves or fruits are capable of being infected. This fact has been firmly established both by observations in the field and by direct experiments. In July the ordinary summer pruning was carried out in the nursery at Long Ashton, and at the end of September a good number of young shoots had developed from the dormant buds which had thus been roused into activity. On the susceptible varieties this young foliage was heavily infected while the mature foliage showed no recent infection. Aderhold has noted the liability of the young organs to be attacked, but recently Wallace cited instances where *V. inaequalis* spread rapidly amongst apples in storage. Whilst under certain conditions therefore mature organs may be successfully infected, it appeared certain in the case of the trees under inspection at Long Ashton that little late infection took place.

To avoid possible misunderstanding it should be explained that the use of the term "infection" in the previous paragraph includes not merely the penetration of the fungus into the tissues of the host, but also its development afterwards to such a degree that the infected area carrying a crop of conidia can be seen with the naked eye. It is possible that penetration may occur on older foliage and fruit: but if so, the fungus appears unable to grow to any appreciable extent in the tissues of the host.

In view of the above it is clear that normal penetration of the cuticle and further growth of the fungus must be followed on very young leaves. When the appressorium is firmly established a growth of the hypha into the cuticle takes place, beginning as a small bulge from the centre of the attached disc (Fig. 5 and compare Figs. 11, 12). The hypha usually grows directly into the cuticle at right angles to the surface of the leaf, but occasionally it is inclined obliquely (Figs. 6 and 7). As it penetrates inwards it very often becomes enlarged, possibly in order to secure the further attachment of infecting hypha. The cuticle being extremely thin in the case of young leaves, the wall of the epidermal cells is reached almost at once by the hypha which then begins to grow between the epidermal wall and this cuticle, forming a plate-like mycelium of very characteristic appearance (Figs. 2 and 3). The cells at first are very thin and the plate is on y one cell in thickness, but soon the fungus gets food from its host and the hyphae begin to

increase in size and divide so as to form a pad of cells, sometimes pushing the cuticle outwards, sometimes crushing the epidermal wall inwards. This subcuticular mycelium continues to grow out in all directions, sometimes long arms of the mycelium projecting from the original point of infection. It may at first consist of one long hypha which will divide to form the mycelium afterwards, but usually the mycelium spreads in a plate-like manner. The cells always remain hyaline and do not become brown as in the ordinary superficial mycelium. The growth of the mycelium seems to be hindered to some extent at the junctures of the epidermal cells, for it is not uncommon to find one epidermal cell covered with mycelium and most of the neighbouring ones quite free (Fig. 4).

The exterior walls of the epidermal cells are usually convex, and projecting portions of the cuticle fit in between adjacent cells. In passing from above one epidermal cell to the next the fungus almost always keeps between the cuticle and the epidermal walls without dissolving away the former to any great extent. Therefore it seems probable that for mechanical reasons it might be difficult for the fungus to pass over these junctures, and especially would this difficulty be felt by the older mycelium growing out laterally from the original invading strand rather than by the young hyphae meeting the juncture at right angles. The attack of one of these scab fungi at first has no apparent influence on the epidermal cells, the nuclei remaining in their normal position which is near the lower walls; but later various changes may take place, the cell contents being frequently conglomerated into a granular gumming substance, especially with artificial infections made in bell jars. A substance which gives the red colour characteristic of wound gum, with phloroglucin and hydrochloric acid, has also been found excreted into the intercellular spaces of the leaf of the pear when its lower surface is attacked. The final effect usually produced on the affected leaf is the extension of the palisade layers into a kind of phellogen round the scabbed area, this development frequently causing the leaf to be somewhat curled.

Sometimes in the thickened region of the cuticle above the vertical walls of the epidermal cells there appears a structure resembling a hypha cut in transverse section and a similar structure can occasionally be seen strictly following the junctions of the cells, if an inoculation be examined in superficial view (Fig. 25). It does not seem that the infecting hypha always behaves in this manner before it enters upon its true subcuticular position: but when it is remembered that the

appressoria appear to be formed over the same points, it seems to afford some significance, the importance of which is discussed below.

The subcuticular mycelium having been formed in the leaf, the uppermost cells of the stroma begin to enlarge, and push out the cuticle until they burst it open and form the conidiophores from which conidia begin at once to be cut off.

The method by which the conidiophore passes through the thick cuticle on the fruit may be of interest as affording a comparison with the method of entrance. There are two ways in which it does this: (*a*) by eating away the cuticle in exactly similar manner to which it infects, (*b*) by growth of the subcuticular stroma at right angles to the surface so that the cuticle is burst off. The fungus lives typically between the cuticle and the outer wall of the epidermal cells, but on the fruit it does not simply force its way between the layers. It also partially eats away the cuticle as it is invariably seen that this layer is thinner where it covers the mycelium. Sometimes at the edge of the scabbed patch the actual hypha can be seen completely embedded in the cuticle. Hence there is absolutely no doubt that there is some cuticle dissolving excretion exuded by the fungus in its passage through this layer.

It is not purposed to continue a description of the life-history further, since in a resistant variety the fungus never reaches a stage beyond that already described. In the following account of the resistance and susceptibility of the hosts, reference will be made again to various stages in inoculation of other portions of the plant; but the above account is typical of what happens in the normal infection of a young leaf.

The Question of Immunity.

Perhaps no other important disease exhibits such irregular behaviour as these fungi as regards their immunity. For example, it is well known that one variety may be heavily attacked one year and remain almost immune the next, although the organism may be quite near. Wallace says "it is found that certain varieties may be resistant in one year and susceptible in another year under conditions which for average varieties are as favourable to the disease in the one case as in the other." Salmon reports that at the Wye College Cox's orange pippin had almost every shoot attacked by *V. inaequalis* but at this station extremely little of this fungus was found on the variety at all during 1914. It is considered that the suggestion which at once occurs, viz. that this

characteristic behaviour of the disease may be due to variations in the climatic conditions at the time when the hosts are in most susceptible condition, is not a sufficient explanation, and Wallace thinks that the fungus itself is adapting itself to life on the "resistant" hosts. Again, too, there is great variation in the parts of the host attacked. Sometimes it is especially the stem, sometimes the leaves, sometimes the fruit. Again, the part of the host especially attacked, whether leaf, stem, or fruit, varies considerably under conditions of which we know little. The absence of adequately definite facts makes it at present unprofitable to formulate hypotheses to account for these phenomena, but on fuller knowledge it seems probable that much of the accessory factors connected with the immunity of these fungi might be explained. In the following instance some such explanation is attempted. It is well known that the pear fungus appears on the fruit first and on the foliage afterwards, whilst in the case of the apple the conditions are reversed. Now it seems likely that the very thick woolly coating of hairs on the young fruit of the apple very efficiently protect it from becoming wetted and consequently infected. Later when this covering disappears infection very readily takes place. There are many fungi in common with *Venturia* which attack their hosts in a more or less localized portion, and it is usually the young organs which are most susceptible. There seems to be a definite correlation between the age of the leaf and its powers of resistance. We might point to a parallel amongst animals in the everyday fact that the young are more susceptible to certain diseases than adults. In the case of plants it is not known whether this increased resistance accompanying age is due to the better protection of the host against attacks of fungi, such as might be afforded by the thickening of the cuticle, or whether the limiting factor is intimately associated with the life of the living cell, and the fungus is killed after penetrating the cuticle. Definite experiments were therefore made to find out what happens when spores attack the mature leaves of various varieties of some of which the young organs are susceptible. For this purpose the mycelium from a pure culture was used for inoculations, in order that the fungus might have a larger reserve of food material to sustain itself in the attack than that contained in the spore. In the case of the pear William's Bon Chretien, a susceptible variety, the fungus developed normally up to the stage of the formation of the appressorium and the issuing of the hypha from its underside into the cuticle. Instead, however, of the infection hypha penetrating completely through the cuticle, and developing

immediately a subcuticular mycelium, it showed a great tendency to grow out horizontally into the cuticle (Fig. 21), which on the older leaves is of sufficient thickness to allow this. There seems some preference of the fungus for the outer portion of the cuticle, rather than that adjacent to the epidermis, but finger-like processes, especially from the underside, are given off as branches from the main hyphae. Sometimes these processes reach the epidermal cell-wall and the formation of a subcuticular mycelium takes place: but it was never observed to reach any advanced stage in development, always remaining very simple (Fig. 22). After a varying interval of time the cells of the fungus die off, their contents becoming converted into dark brownish spherical granules. From very many inoculations on mature leaves, both in bell jars and on the trees in plantations, no conidia have ever been produced. Even when the mature leaves of a resistant variety are inoculated, the same course of events is followed. Fig. 20 shows the dead hyphae of *V. pirina* in the cuticle of the Catillac pear, a resistant variety which was very heavily inoculated with pure mycelium. It will be noticed also that the epidermal cells show the beginnings of the formation of a phellogen, which in the normal progress of the disease is developed after the attack has developed for some time, and which has been reported by Voges.

In the inoculation of the mature fruit much the same thing happens, although the cuticle here being much thicker it is much easier to follow what takes place. The infection hypha from the appressorium grows directly into the cuticle (Figs. 11, 12 and 13) and then at its innermost end swells slightly until it becomes almost spherical (Fig. 14). Growth can now proceed in all directions, but much more easily in a plane parallel with the surface of the fruit (Fig. 15). Occasionally, however, it penetrates slowly, following its original course (Figs. 16 and 17). The cuticle is apparently laid down in layers, for with all kinds of stains the innermost layers almost invariably take on a deeper colour than the outer ones, and distinct striations can nearly always be seen, especially where it covers the juncture of neighbouring cells of the epidermis. The direction of growth of the hyphae now seems to follow these striations sometimes to an astonishing length, suggesting perhaps that the physical character of the cuticle is an important factor (Figs. 18 and 19). It has been found extremely difficult to infect successfully the mature fruit (using the term "infect" as explained above); and although this is reported to occur under certain conditions the ordinary course of events seems to be for the fungus to die off in

exactly similar manner as when attacking mature leaves as above described.

Although great differences occur between the attacks on certain varieties in successive seasons, yet there are some varieties which always remain highly resistant, if not completely immune, to this disease. It was therefore interesting to determine the fate of the fungus on the young leaves of resistant varieties. For this, Bramley's Seedling and Newton Wonder apples were selected as resistant varieties for *V. inaequalis*, with Cap of Liberty, a well-known cider apple, as the susceptible variety for comparison; also the pear William's Bon Chretien, a variety susceptible to *V. pirina*, was infected, being regarded as resistant to *V. inaequalis*. All were inoculated with conidia of *V. inaequalis* obtained from the leaves of the "Cap of Liberty," and the results were very similar. Appressoria were formed as usual, infection hyphae sent out into the cuticle, but in resistant varieties the adverse effect of the host was quickly felt (Figs. 23, 24, 25) although sometimes the fungus succeeded in penetrating completely through the cuticle and forming a subcuticular pad. This usually appeared quite unhealthy, the cells being smaller and narrower. The cuticle being so thin no horizontal development of the mycelium in it could be detected except in a few cases. Inoculations of *V. pirina* also were made on the fruit of the apple, King of the Pippins, which is susceptible to *V. inaequalis*, but in no case was the infecting hyphae seen not to have penetrated into the cuticle. The apple fungus easily penetrated into the cuticle of the pear and the pear fungus that of the apple. On Bramley's Seedling the fungus exhibited a preference for that portion of the cuticle above the junctures of the epidermal cells already referred to (Fig. 25). Eventually in the resistant types the mycelium ceased to grow and practically died off. With the susceptible types on the other hand a healthy subcuticular mycelium was quickly formed and developed in the normal way described above until the production of conidia resulted.

General Considerations.

The problems of immunity are particularly difficult because in dealing with them we have to deal with fundamental life processes which do not lend themselves to experimental conditions. All the work which has been done towards the elucidation of the limiting factors of immunity has been done with obligate parasites such as the Mildews and the Rusts, but unfortunately none of these fungi will

grow apart from the host. The facultative parasite affords a line of attack of this difficult problem, for after a determination has been made of what can be seen to happen to the fungus within the host of both susceptible and immune varieties it might be possible to submit the fungus to culture apart from the host and in media which may have been directly derived from the host. If we are to attempt to enquire whether the non-infection of an immune form is due to a toxin, or anything of a similar nature, we must follow some such line as this. *Venturia* is quite a unique fungus in its normal habitat between the cuticle and the host: and although the process of infection and subsequent manner of growth in the host may be peculiar to itself, yet it may be well to discuss it in relation to what is known of other fungi. It is not proposed to review the literature on this question in any detail, since these results would not warrant such an exposition, but a brief outline of the principal work has been done, especially that associated with *Venturia* may be given.

Büsgen[1] found with *Venturia* that the appressoria are formed frequently over the epidermal walls perpendicular to the surface, and endeavoured to show that diffusion of some substance takes place at this place and which acts chemotropically on the germ tube.

Aderhold (*loc. cit.*) holds that no particular chemotactic stimulus is necessary, but that there is simply a strong diffusion of the ingredients of the cell contents; this, however, he was not able to ascertain in demonstrable quantities in living tissues. He held that at the junctures of the epidermal cells the external cell-wall must have other properties than those of the flat surfaces of the remainder of the external walls. He records experiments which are not very conclusive but from which he gathers that the pectates (especially potassium pectate) act chemotropically on the fungus and suggests that the middle lamella may so act in nature.

In addition there is the work of Myoshi, Nordhausen, Fulton and others on general questions of chemotropism, but, so far as we know, no other paper discusses the question in relation to *Venturia*.

The question of how the infecting hyphae pass through the cuticle must take into consideration the nature of the cuticle itself. The work which has already been done does not give much information, being chiefly concerned with the distinction of cuticle from cork, whether cuticle contains any cellulose and similar chemical problems.

[1] Büsgen, M., *Ueber einige Eigenschaften der keimlinge parasitische Pilze. Bot. Zeit.* 1893, p 53.

The cuticle is a protective covering layer to all young parts of plants and hence must be capable of very rapid extension. It is not known how such growth takes place, whether the outer walls of the epidermal cells become gradually converted into cutin or whether the cutin itself is a secretion of the cell. The cuticle, however, must not be regarded as being a simple homogeneous body. Von Höhnel[1] in 1878 stated that the external layers of the cuticle are free from cellulose, whereas those layers bordering on the external walls of the epidermal cells represent cellulose saturated with cutin. More recently Géneau de Lamartiere in 1906 has seen fit to distinguish the former as the epicuticle. With all the common stains it is found that the portion of the cuticle next the epidermal cells is coloured more deeply than the rest of the cuticle, particularly in the projections which fit between the adjacent epidermal cells; and moreover, the general staining of the cuticle suggests that it has been formed in layers. The outer layers, being continually exposed to complete desiccation, must be under greatly different conditions from those next to the epidermis. Hence it appears probable that the cuticle has a structure of its own: and this may be an important factor in the penetration of the infection hyphae through it.

The permeability of the cuticle is of interest, as regards the chemotropic attraction which certain substances have on fungal hyphae. That substances can diffuse through the cuticle in some cases cannot be doubted, since the copper of Bordeaux mixture slowly passes into leaves of certain plants, such as potatoes, which have been sprayed with it (Barker and Gimingham[2]). Whether any substance which may render the copper in such cases soluble diffuses out through the cuticle is not known, and the position is similar with regard to the diffusion of substances possibly chemotropic to fungal hyphae. Nevertheless it must always be remembered that such a thing may happen in nature.

The observation that the appressoria are formed frequently over the juncture of epidermal cells, seems to be justified from a careful examination of inoculations in surface view. But it is by no means the case that they are formed only in these positions. On examining 300 appressoria, 26 % were found to be over the centre of the cells and between 14–19 % did not touch the junctures although they were perhaps near them. If we take into account the relative sizes of the appressoria and the cells, this result may not appear to be particularly unexpected. The area within which an appressorium if it fell would

[1] See Czapek, *Biochemie der Pflanzen*, p. 702, 1912 Ed.

[2] Barker and Gimingham, *Ann. Applied Biology*, Vol. I. p. 19.

touch the juncture of the epidermal cells would be bounded by a line, the breadth of the appressorium within the edge of the cell; and taking the relative sizes of the diameters of the cells and appressoria roughly as 6 : 1, we should find this area would be $\frac{5}{4}$ that remaining. Hence we might expect the appressoria to touch the junctures of the epidermal cells more often than not. On the other hand, however, other fungi as well as bacteria are said to show a similar liking for that part of the cuticle above the junctions of the walls. The elaborate paper of Fulton, in which he calls in question the whole of the work done on chemotropic attraction of fungal hyphae, makes us suspicious of accepting altogether the works of earlier investigators and it becomes more and more evident that a further study of chemotropism is necessary for the progress of enquiry into the question of the attack of parasitic fungi. It is not yet established whether chemotropism does exist at all; and not until we know, not only whether it exists but also whether it plays any part in infection, can we hope to attempt to solve the question why the fungal hypha enters the host.

If some chemotropic substance does influence the direction of growth of the germ tube, it must either be the exterior layers of the cuticle or something formed interior to them and then excreted. There is no reason to suppose that the exterior of that portion of the cuticle covering the perpendicular epidermal walls has peculiar properties. Nordhausen has suggested that the mechanical checking which the germ tube undergoes on crossing a groove or the collection of water in it may account for the predilection of the appressoria for this position, yet the behaviour of appressoria is quite similar on varieties like Port and William's Bon Chretien which have no grooves (see Figs. 26, 27 and compare Fig. 28). That the cuticle which covers the junctures of the epidermal cells is, however, different from the remaining is shown by the different staining properties it possesses; this fact, taken in conjunction with the occasional occurrence of hyphae embedded there, suggests rather pointedly that this may be a substance chemotropically attractive to the germ tube. At the best, however, *this* chemotropism can be only an accessory factor in infection since hyphae can penetrate the cuticle quite well in the middle of the epidermal cell-walls.

The growth of the infection hyphae from the appressoria through the cuticle itself is interesting in connection with the part played by chemotropism. If the hypha entered solely because attracted by the substances in the epidermal cells or cell-walls of the host, we should suspect that it would bore directly through the cuticle to reach the

subcuticular position. But although the cuticle of organs susceptible to attack is very often so thin as to prevent the horizontal growth of the infection hyphae in it, yet occasionally one finds stages as represented in the Figs. 6 and 7. These figures suggest that there is no guiding influence towards the epidermis, but that the fungus simply eats its way slowly through the cuticle until it arrives between the cuticle and epidermal cell-wall. With mature organs of both susceptible and resistant varieties where the cuticle is thicker, we have still more interesting cases. How can the long horizontal growth of the infection hyphae in the cuticle (a very frequent occurrence) be explained? Does it not rather suggest in place of an attracting substance the presence of something which is repulsive to the invading hypha? The physical layering of the cuticle may have something to do with the direction of growth, but this horizontal habit is not confined to fruits but is also exhibited in mature leaves, where the layering of the cuticle is not nearly so evident on staining. Of course, the tendency is most clearly developed in resistant organs because the young susceptible parts of plants have very thin cuticles, but that it should occur at all strongly negatives the view of the germ tube being attracted by the cell sap of the host. The conclusion seems unavoidable that the fungus infects *in spite of* the host, and that chemotropism if it acts at all must play a very insignificant part in the process.

It has been shown that immunity does not depend on freedom from the initial attack, any more than in the case of the rusts; immunity there depends upon the non-entry of the infection tube into the host. What the limiting factor in immunity is, we can only speculate—it may be simple starvation of the fungus, as suggested by the gradual reduction of growth, or it may possibly be the formation of some toxic substance. With such possibilities existing it might be well to mention here some experiments which were made on the growth of the conidia of *V. inaequalis* in the expressed sap of the young leaves of certain varieties of apples. Young leaves of King of the Pippins (susceptible) and Bramley's Seedling (resistant) were pounded in a mortar and the sap then squeezed out of them. Conidia were then sown in the sap and hanging drop preparations made which, although by no means free from bacteria and yeasts, remained sufficiently pure for the one or two days necessary for the experiment. Control drops were set up with water instead of the sap medium. In all cases the growth of the conidia in the sap was very much slower than in water and a much larger percentage did not germinate. On diluting the sap, the conditions

of germination were gradually improved until in media of which the ratio of sap to water was 1 : 10 no difference from the water controls could be observed. A few further experiments were made with Newton Wonder (resistant) and Cap of Liberty (susceptible) which as far as they went coincided with the results given above. In these sets of preparations the conidia appeared to grow better in the sap of the susceptible varieties than in that of the resistant kinds: but the approach of winter rendered it impossible to carry this work any further for the time being. The little which has already been done seems to support the view obtained from the study of microscopical preparations that the host is antagonistic to rather than attractive towards the parasite.

The facts which are recorded in this paper are therefore considered to suggest that the appressorium, being formed as the result of mechanical stimulus as shown by Aderhold, penetrates into the cuticle, feeding on it as it goes and finally reaching its normal habitat between the cuticle and epidermis where it flourishes, if the attacked variety is susceptible.

Immunity is shown not to depend on the protection of the cuticle and indications are recorded which suggest the probability of the cell sap of the host being in all cases antagonistic to the fungus.

In conclusion I should like to express my deepest thanks to Professor B. T. P. Barker, M.A., at whose suggestion the work was begun, and who throughout has rendered invaluable aid by helpful criticism and advice. I am also indebted to him for facilities for working at the Agricultural and Horticultural Research Station of the University of Bristol.

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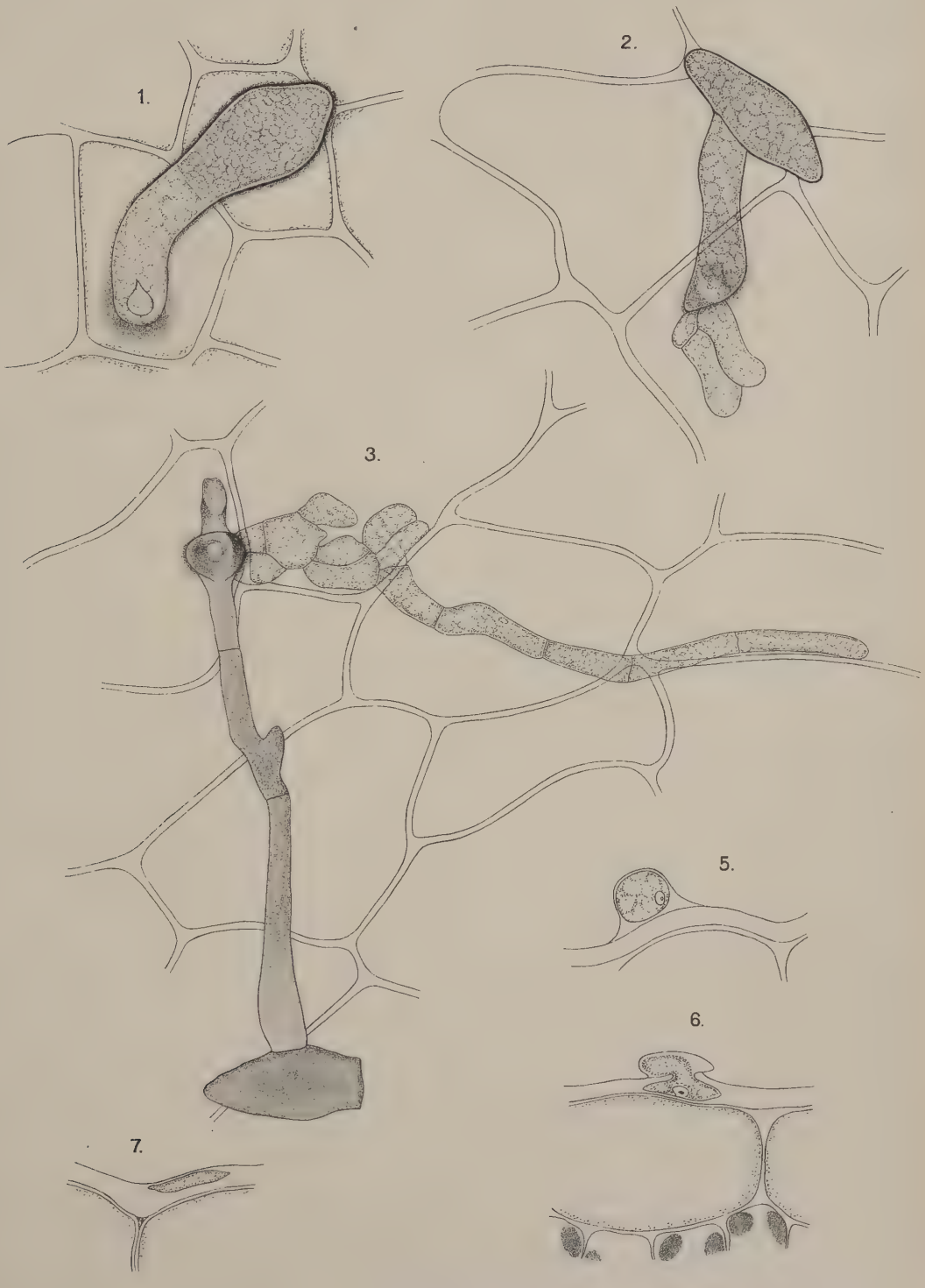

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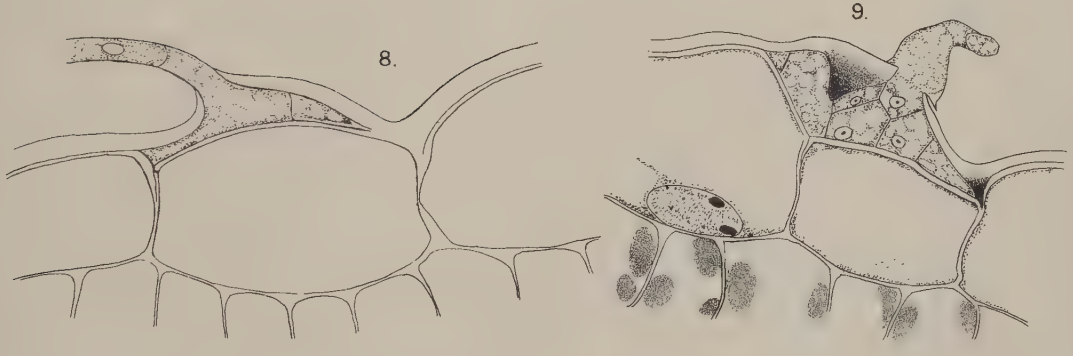

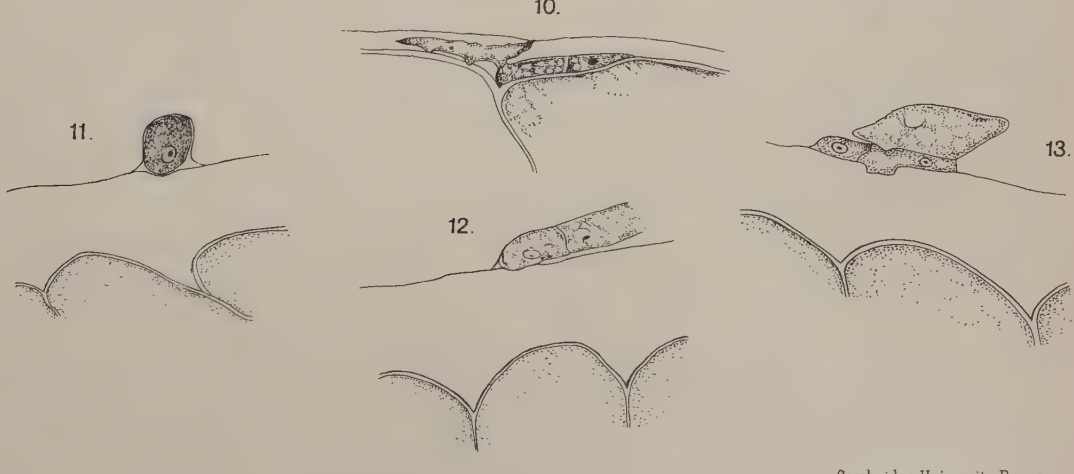

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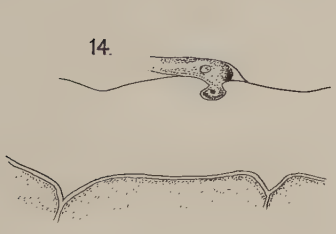

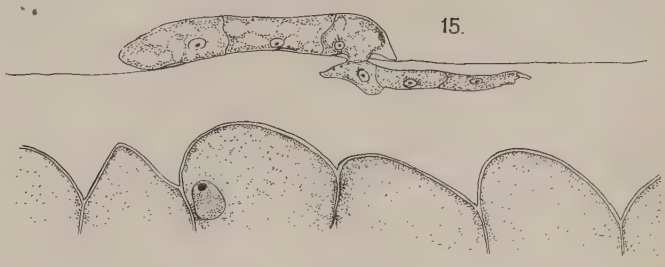

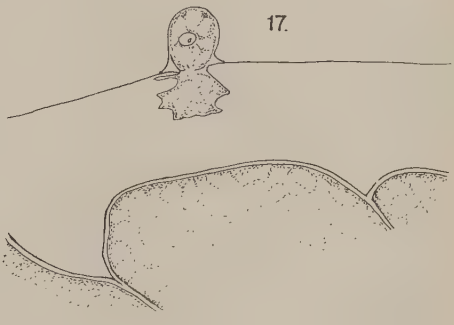

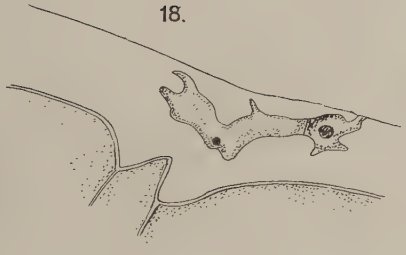

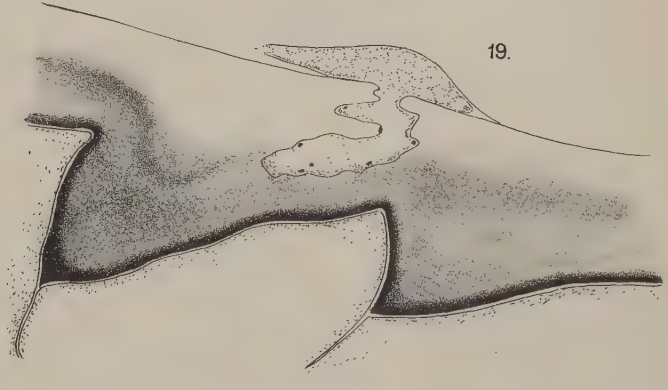

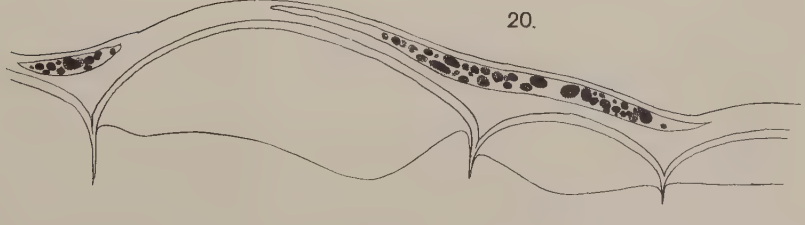

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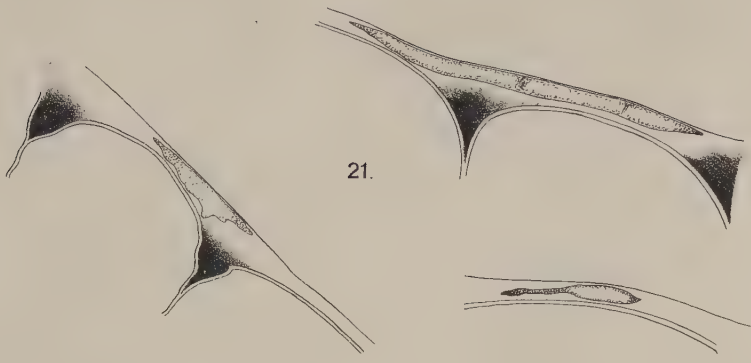

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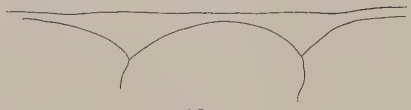

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WINTER COVER WASHES.

By A. H. LEES, M.A.,

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Winter cover washes or more properly late spring cover washes were first tried on the large scale by Mr Howard Chapman of Kent. He found by experience that a lime wash applied as late as possible before the buds burst in spring produced a very decided lessening of Psylla attack and consequent increase of crop. Cover washes have also certain other subsidiary but very real advantages:

(1) They can be applied when labour is easily obtainable. A summer wash has to be put on at the end of April, nearly two months later, when labour is urgently needed for other operations.

(2) They tend to keep the bark clean.

(3) They add a small amount of lime or chalk to the soil.

Since its introduction lime wash has been tried by many growers, some of whom have become enthusiastic advocates of it, while in the hands of others it has produced no apparent good. It seemed therefore desirable to make some investigation into its action. Two hypotheses were current to account for its good action, since undoubtedly it has had good action in some places and under some conditions. The first suggested that its action was due to the causticity of the hot lime, which had some effect on the protoplasm inside the egg or at any rate so influenced the egg shell as to render the ovum fatally susceptible to outside conditions. The second supposed that the lime covering had no direct action but only an indirect mechanical one, effectually sealing in the eggs and preventing the hatching of the enclosed larva. It was obvious from the outset that the first explanation was unlikely. When one considers that the chitin of insect eggs can resist being boiled in strong caustic soda, it is not likely that the feebly caustic lime would affect it. The second thus appeared a more

likely hypothesis. Working on this it is at once apparent that to make such a wash most efficient certain conditions must be fulfilled. These are:

(1) It must give a thick covering.

(2) It must resist all external conditions causing lessening of the coat when once on the tree, *i.e.* it should not flake when dry or wash away when wetted by rain.

(3) It should be applied as late in the spring as possible.

(4) The materials should be reasonably cheap and easy to get.

(5) It should be easily made.

All the experiments hereafter described had to be done in the dead season, beginning in the autumn of the year and ending in the late spring of the following year when the buds had begun to burst. They may be grouped more or less in a chronological order in order to retain the sequence of ideas.

Season 1912–13.

Laboratory experiments.

Experiments were begun to find some mixture that was more resistant to erosion than lime alone. In the first trials twigs were dipped into the various mixtures and allowed to dry in the laboratory.

It was found, however, that this method gave unsatisfactory results, as the twigs themselves soon dried and contracted away from the coating of material applied to them, so that the best wash under these conditions soon began to flake. On the living twig this is not so. In all subsequent laboratory experiments the washes were poured upon ordinary 3×1 microscope slides and allowed to drain as they dried. The smooth surface of the slide was an additional guarantee of good sticking qualities. In practice, in the field, twigs are always slightly rough so that any wash adhering well to glass slides should do so quite as well when applied to a tree. Plain lime wash at the rate of 2 lbs. to the gallon of water was used as control. It having been frequently stated that the addition of waterglass or sodium silicate improved the adhesiveness, this was first tried. All quantities are calculated in pounds of material to pounds of water or in grains per c.c.

The following (with the salt left out) recommended by Theobald

Lime	Waterglass	Water
20	1	100

produced no improvement; if anything it was inferior to plain lime wash. This is not surprising as calcium silicate, which is formed by the action of lime on sodium silicate, is a hard brittle body and not likely to give adhesiveness in the quantity used above. Greater strengths would prove too expensive. The addition of salt, according to the following formula:

Lime	Salt	Water
20	2	100

gave the same negative result.

It having been brought to the author's notice that tallow was used by many firms who did outside lime washing, the following was tried, the tallow being added as the lime was slaking:

Lime	Tallow	Water
50	2	250

This formula proved of doubtful value.

Field experiments.

The lime and tallow wash was tried at five different centres in counties within the advisory area of the Bristol University Research Station, the lime and salt at eight and the whiting and size at three. Control experiments were also done at Long Ashton.

The whiting and size formula gave very good results but as a practical wash it is far too expensive.

Lime and tallow showed no superiority over lime and salt. Sometimes one gave a better result and sometimes the other, and it was clear that good sticking power depended more on the freshness of the lime than on any other factor.

Season 1913–14.

Laboratory experiments.

The whiting and size wash, though giving a good coat, proved far too expensive. Less quantities of size than that used above gave too thin a coating.

Accordingly an attempt was made to obtain a cheaper form of glue. After some trial one was obtained at about 4*d.* a lb. in hundredweight quantities. This brought down the cost to about 5*d.* a gallon which was still prohibitive. It was found that smaller quantities of glue

gave sufficient adhesive power but not sufficient covering power. Starch paste was therefore tried to remedy this according to the formula:

Whiting	Glue	Starch	Water
8	$\frac{1}{8}$	$\frac{1}{4}$	10

This gave a thick and fairly firm coat. Less starch gave too thin and loose a coat while more glue became too expensive. In order to get a cheap form of starch, ordinary flour was used after being converted by hot water into paste.

Three formulas were made up with varying amounts of flour and glue. The results and costs are included in the table below:

No.	Whiting	Glue	Flour	Water	Result when dry	Cost per gallon
(1)	8	$\frac{1}{8}$	$\frac{1}{4}$	10	Fair coat	$2\frac{1}{1}\frac{1}{2}d.$
(2)	8	$\frac{1}{4}$	$\frac{1}{4}$	10	Better than No. (1) ..	$2\frac{1}{1}\frac{7}{2}d.$
(3)	8	$\frac{1}{4}$	$\frac{1}{2}$	10	Still better coat ..	$2\frac{1}{1}\frac{9}{2}d.$

The price of all these is rather high and they have besides other disadvantages.

When such a coating is exposed to the action of water it quickly gets washed away owing to the solubility of the glue, but if a small quantity of potassium dichromate is added the glue is rendered insoluble on exposure to light. This action depends on the gelatine of the glue which, mixed with dichromate and exposed to light, becomes insoluble.

The following formulae were then tried:

Whiting	Glue	Flour	Pot. dichromate	Water
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{16}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	10

In all cases the addition of the dichromate caused a great thinning in the consistency of the liquid and a poor coat resulted. On trying starch again according to the formulae:

Whiting	Glue	Starch	Dichromate	Water
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	10
8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{64}$	10

good covering power and adhesiveness were obtained in both cases. It was necessary therefore to obtain a cheap form of starch and this was found in "Farina," a potato flour which cost about 2*d.* a pound when bought by the hundredweight. Accordingly the following two mixtures were tried:

No.	Whiting	Glue	Farina	Water
(1)	8	$\frac{1}{8}$	$\frac{1}{4}$	10
(2)	8	$\frac{1}{8}$	$\frac{1}{8}$	10

Both gave good coverings and were more satisfactory than those made with ordinary starch.

With the idea of incorporating a fungicide Bordeaux mixture was added, but it caused great thinning of the liquid.

The same result was obtained when copper sulphate was added. The addition of flowers of sulphur, with the same end in view, though it caused no thinning was unsatisfactory as the dried coat showed great tendency to flake.

The cost of No. (2) of the above table is 2*d.* a gallon of which the whiting costs $1\frac{1}{4}d.$, the glue $\frac{1}{2}d.$ and the farina $\frac{1}{4}d.$

Owing to the expense of the whiting, due chiefly to the large quantities necessary to produce a thick coat, lime was again tried as the covering material. The following mixtures were tried with the results included in the table:

Lime	Glue	Farina	Water	Result
2	—	—	10	Poor covering
2	$\frac{1}{2}$	—	10	Poor covering
2	$\frac{1}{8}$	$\frac{1}{8}$	10	Very good but flocculent and inclined to flake
2	—	$\frac{1}{4}$	10	Too thick but not firm enough
2	—	$\frac{1}{8}$	10	As thick but not coherent and flaking when dry

In order to stop this flaking a mixture of lime and whiting was tried with the idea that the different sized particles thus introduced might interlock and so prevent the flaking:

Lime	Whiting	Glue	Farina	Water
14	7	1	1	80

This mixture, though it appeared not to flake at first after a few days did so. It was suggested that the addition of cressyllic acid which is supposedly used in some distempers might give good adherence. 1, 2 and 5 per cent. added to the ordinary lime wash, however, gave mixtures which flaked as badly as the control.

Effect of aluminium salts.

The extremely gelatinous nature of aluminium hydroxide is well known and it was thought that by incorporating it with ordinary lime wash adhesiveness might be obtained. Accordingly aluminium sulphate was added. Its reaction with calcium hydroxide gives aluminium hydroxide which thus becomes thoroughly well mixed.

The following mixtures were tried with the results included in the table below:

No.	Lime	Aluminium sulphate	Glue	Copper sulphate	Water	Result
(1)	2	$\frac{3}{5}$	—	—	10	Thick coating when wet, very hard and firm when dry
(2)	2	$\frac{3}{5}$	$\frac{1}{8}$	—	10	Thick coating when wet, but not quite so good when dry as (1)
(3)	2	$\frac{3}{5}$	—	$\frac{1}{20}$	10	Decidedly thinner when wet and powdery when dry
(4)	2	$\frac{3}{5}$	$\frac{1}{8}$	$\frac{1}{20}$	10	Thin when wet and loose when dry

The addition of glue did not improve the mixture, and copper sulphate again caused thinning and loss of adhesiveness.

Substitution of alum for aluminium sulphate.

It being possible to obtain alum at $1\frac{1}{4}d.$ a pound while the cheapest quotation for aluminium sulphate is $2\frac{1}{2}d.$, the former was tried in its place. At the same time iron sulphate was introduced as a fungicide with the results given in the following table:

No.	Lime	Alum	Iron sulphate	Water	Result
(1)	2	$\frac{9}{10}$	$\frac{1}{10}$	10	Too thick
(2)	2	$\frac{9}{20}$	$\frac{1}{10}$	10	Too thin
(3)	2	$\frac{7}{10}$	$\frac{1}{10}$	10	Right thickness

Unlike the copper sulphate, iron sulphate does not cause a thinning of the mixture.

In order to test the rain resisting power of the various mixtures that had been made up, slides covered with them were soaked in water for 24 hrs. The mixtures and results are given in the following table:

No.	Lime	Whiting	Alum	Farina	Glue	Dichromate	Iron sulphate	Cressyllic acid	Water	Result after 24 hrs. soaking
(1)	2	—	$\frac{7}{10}$	—	—	—	$\frac{1}{10}$	—	10	Very good. Still hard
(2)	—	8	—	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{32}$	—	—	10	Resisted fairly well
(3)	—	8	—	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{64}$	—	—	10	
(4)	14	7	—	1	1	$\frac{1}{4}$	—	—	80	
(5)	20	—	—	—	—	—	—	5	100	Poor
(6)	—	8	—	$\frac{1}{4}$	$\frac{1}{8}$	—	—	—	10	Very poor
(7)	—	8	—	$\frac{1}{8}$	$\frac{1}{8}$	—	—	—	10	

The mixtures in this table were subsequently tested in the field (see *Field experiments*, 1913–14) when it was found that No. (2) gave by far the best results. As, however, the whiting therein cost as much as $1\frac{1}{4}d.$ in the total of $2d.$ per gallon of wash, it was necessary to try whether lime could be substituted instead. At the time the fact

that gelatine, the essential body in glue, is insoluble in alkaline solutions was not realized. Lime also appears to decompose glue, as a mixture of the two becomes frothy and the glue loses its properties. The following mixtures were tried with the results included in the following table:

Lime	Glue	Aluminium sulphate	Pot. dichromate	Water	Method of mixing	Result
2	$\frac{1}{4}$	—	—	10	Glue added after slaking	Poor coating
2	$\frac{1}{4}$	—	—	10	Glue added to water before slaking. Poured when hot	Poor coating
2	$\frac{1}{4}$	—	—	10	Ditto but poured when cold	Fair coating
2	$\frac{1}{8}$	$\frac{1}{5}$	—	10	Glue added first	Very thin and poor
2	$\frac{1}{8}$	$\frac{1}{5}$	—	—	The sulphate added first	Fairly good coating
2	$\frac{1}{8}$	$\frac{1}{5}$	$\frac{1}{64}$	10	—	Fairly good

None of these mixtures could be considered satisfactory.

Various other substances were added to the ordinary lime wash with the idea of obtaining a firmer coat. These were miscellaneous in nature and may be included for convenience in one table as follows:

No.	Mixture	Result
(1)	Calcium chloride	About as hard as lime alone
(2)	Solar distillate paraffin in emulsion in the lime	Decidedly soft coat probably due to the oil
(3)	Solar distillate and aluminium sulphate	Also gave a soft coat due to the oil
(4)	Various proportions of skim milk	A soft coating due to the fat contained in the milk
(5)	Calcium chloride then waterglass	Very soft and powdery coat
(6)	Cement in the proportions of 1 : 1, 1 : $\frac{1}{2}$, 1 : $\frac{1}{3}$, 1 : $\frac{1}{5}$	All gave flaky and soft coatings, the softness increasing with the proportion of cement
(7)	Plaster of Paris in the proportions of 1 : $\frac{1}{2}$, 1 : $\frac{1}{3}$, 1 : $\frac{1}{5}$	Less flaky than the cement mixtures, but the flakiness increased with increased proportion of plaster

The failure of the cement was probably due to its drying before proper setting could take place. Under ordinary conditions cement is mixed with a quantity of water so that it has a chance of absorbing some chemically before the mass dries.

Methods of slaking lime.

During the course of these experiments it was obvious that the firmness of the resulting coat depended largely on the manner of slaking the lime. An experiment was therefore started to find the method that gave the best result. The usual way of slaking lime is to add just sufficient water to allow chemical action to proceed, that is, it

is allowed to "dry slake." From previous trials, wet slaking, namely covering the lime completely with water, promised the best results. Taking always lime two parts to water ten parts by weight the following ways were tried:

No.	Method	Result
(1)	Excess of hot water added (in this case ⅓rd total required) applied hot	Good coat
(2)	Ditto but applied cold	Not quite so good
(3)	Excess of cold water added	Decidedly inferior
(4)	Slaked dry with cold water. Then full quantity added	Poor
(5)	Slaked dry with hot water. Then full quantity added	Poor

In these trials hot water gave decidedly the best result. This is probably owing to the completeness of slaking thus obtained. Accordingly, further trials were made with the object of getting conditions which should give complete slaking.

The following methods were tried with the results as given in the table below:

No.	Method	Result
(1)	Made up with hot water and not allowed to stand	Thick but very brittle coat
(2)	Made up with cold water and not allowed to stand	Not so thick or brittle
(3)	Slaked with ½ full quantity cold water. Left for 12 hrs., remaining water added and applied	Rather harder than (2) and slightly brittle
(4)	Made with full quantity cold water. Left for 12 hrs. and applied	Fairly thick and not brittle
(5)	Dry slaked and left for 12 hrs. Then made up to full amount of water and applied	Thin but firm coat
(6)	Made up to full dilution and allowed to stand for 12 days	The mixture became very flocculent and the surface covered with a layer of carbonate. When dried on the slide it gave a very soft and powdery coat
(7)	Ordinary lime coating dried slowly in a moist chamber	It produced a hard marbly coat with softer material underneath
(8)	Lime mixture left in small quantities in a large evaporating dish so as to dry slowly	This produced an exceedingly hard and firm coat

The results from Nos. (1) to (5) clearly show that in cases where the lime was slaked slowly, as when a dry slake was given or the mixture allowed to stand for 12 hours, a firmer, less brittle coat was obtained though not necessarily a thicker one. This result was afterwards confirmed by trials in the field. A dry slake gives a very thin and therefore unsuitable coat for an egg cover in practice. No. (8) gave an excellent coat, no doubt due to its slow drying in an indoor atmosphere containing more than the usual percentage of carbon dioxide.

These conditions formed a solid coat of calcium carbonate not only on the surface but in the lower layers as well, thus making an exceedingly hard and smooth coating. Unfortunately these conditions are impossible to obtain out of doors as drying takes place quickly and only small quantities of carbon dioxide are present.

None of the additions made to the lime improved the coat, while most of them made it distinctly worse.

To test whether carbonating before application improved the mixture, carbon dioxide was passed into a beakerful. When poured on a glass slide and dried a brittle coating was obtained which is quite useless.

Field experiments.

These were first arranged on upright flat-sided posts. The results were subsequently found unreliable.

When sprayed on twigs of a tree the coating is subject to violent movings of bending caused by the wind, which are absent in the case of an upright post. It was found that such bendings of the dried coat was largely instrumental in causing flaking. The trial lasted ten days in December during which much rain was experienced.

No.	Lime	Cressyllic	Whiting	Glue	Farina	Dichromate	Alum	Iron sulphate	Water	State when wet	Result after 10 days
(1)	20	2	—	—	—	—	—	—	100	Moderate coating	Largely washed away
(2)	—	—	8	$\frac{1}{8}$	$\frac{1}{4}$	—	—	—	10	Moderate coating	Showed slight signs of thinning
(3)	—	—	8	$\frac{1}{8}$	$\frac{1}{4}$	$\frac{1}{32}$	—	—	10	Moderate coating	Showed very little signs of thinning
(4)	14	—	7	1	1	$\frac{1}{4}$	—	—	80	Moderate coating	Very good and thick coating
(5)	2	—	—	—	—	—	$\frac{7}{10}$	$\frac{1}{10}$	10	Thinned down before applying as too thick to go through nozzle	Very poor
(6)	2	—	—	—	—	—	$\frac{6}{10}$	$\frac{1}{10}$	10	Do.	Do. Thinned in places
(7)	2	—	—	—	—	—	$\frac{5}{10}$	$\frac{1}{10}$	10	Unstrained and thrown on	Thinned in places and flaked
(8)	2	—	—	—	—	—	$\frac{3}{10}$	$\frac{1}{10}$	10	Do.	Do. Thinned rather more than (6)
(9)	2	—	—	—	—	—	$\frac{1}{10}$	$\frac{1}{10}$	10	Do.	Do. Too thin when applied
(10)	$1\frac{1}{2}$	—	—	—	—	—	$\frac{7}{10}$	$\frac{1}{10}$	10	Strained, sprayed, etc.	Showed very little signs of wear
(11)	1	—	—	—	—	—	$\frac{5}{20}$	$\frac{1}{20}$	10	Ditto but too thin	Far too thin
(12)	$1\frac{1}{2}$	—	—	—	—	—	$\frac{3}{10}$	$\frac{1}{10}$	10	Appeared most suitable	Thinned rather badly

Practically both (5) and (6) were too thick to put through a spraying machine. As alum gave disappointing results, aluminium sulphate was substituted to avoid the presence of the soluble potassium sulphate. The following mixtures were tried:

No.	Lime	Al. sulphate	Iron sulphate	Water
(1)	1½	$\frac{7}{10}$ (=$\frac{7}{10}$ alum)	$\frac{1}{10}$	10
(2)	1½	$\frac{5}{10}$ (=$\frac{5}{10}$ alum)	$\frac{1}{10}$	10

No. (2) gave too thin a coat while No. (1) appeared satisfactory. The better mixtures of those tried on the upright posts were then sprayed on to trees with the results included in the table below:

No.	Lime	Whiting	Glue	Farina	Dichromate	Al. sulphate	Alum	Iron sulphate	Water	Result after three weeks	Number of trees sprayed
(1)	—	8	⅛	¼	—	—	—	—	10	Washed off badly Surface soft	2
(2)	—	6	⅛	¼	$\frac{1}{32}$	—	—	—	—	About the same condition as when applied. Surface gritty	2
(3)	1½	—	—	—	—	⅛	—	$\frac{1}{10}$	10	Washed off badly. Surface very flaky	3
(4)	1½	—	—	—	—	½	—	$\frac{1}{10}$	10	Ditto	2
(5)	14	7	1	1	⅛	—	—	—	80	Washed off rather badly. Surface flaky	2
(6)	1½	—	—	—	—	—	$\frac{5}{10}$	$\frac{1}{10}$	10	Washed off badly. Surface very flaky, possibly a little worse than (3) and (4)	2
(7)	1½	—	—	—	—	—	$\frac{7}{10}$	$\frac{1}{10}$	10	Ditto	3

The weather in the three weeks of trial included rain, snow, frost and wind.

Of these mixtures by far the best was (2). The amount of whiting was decreased from eight to six as the larger amount was difficult to incorporate with the water required by the formula. The aluminium sulphate and the alum mixture were disappointing as they had given good results in the laboratory.

To test the effect of keeping lime mixtures for some time before applying them the following formulae were tried with the results included in the table below:

No.	Lime	Water	Method	Result after two months
(1)	2	10	Applied after keeping for 2 days	Stuck better than (2)
(2)	2	10	Applied hot	Not so good as (1)
(3)	2	10	Applied after being froze for 4 days	Came off very quickly
(4)	3	10	Applied hot	Somewhat better but not good

From results from (1) and (2) it is clear that it is best when possible to keep the lime mixture at least some hours before applying. This

result was confirmed in some experimental spraying done in Herefordshire. The explanation is probably this. When lime is slaked, at first there is a violent action which soon subsides. In ordinary parlance the lime is now "slaked" but chemical action goes on more slowly for some hours. A 40 gallon barrel of lime wash made in the evening was still warm the next morning, showing that chemical action had been continuing. If applied directly after the first violent action has ceased, in the words of the grower put on "hot," further slow slaking proceeds when on the tree, resulting in expansions of particles in the coating. The expansion of small particles act like levers on the rest of the coat, pushing and levering off particles that are completely slaked and dry. The net result is that slaking sets in. This, however, is certainly not the only cause of flaking. Wind causes much damage on the smaller boughs. Owing to the bending to and fro of the twig, at first the coat is too small, when the twig is convex, and then too large, when concave. Another cause is frost after wet. Beating rain causes washing off but not flaking. Insufficient slaking explains the fact that good coatings often show completely bare patches sooner than poor coatings. The poor coatings are generally made from partially slaked lime or from a mixture too poor in lime. In each case a more perfectly slaked mixture is obtained but a mixture which is, of course, much inferior in egg covering powers.

A thick mixture like the 2 lbs. to 1 gallon formula, allowing some hours for complete slaking, not only gives a firmer coat but also a thicker one, as one gets more of the very fine particles which are the most important in forming a thick coat. These particles seem so small that they aggregate when wet in an almost gelatinous manner so that the mixture has quite a distinct viscosity. When dry this gelatinous form disappears and does not reappear on wetting.

Of all the washes so far tried the whiting, glue, farina, dichromate formula gave by far the best results and it was therefore tried more extensively at Long Ashton.

It was also tried at centres in the three counties of Gloucestershire, Worcestershire and Herefordshire on trees well infested with Psylla eggs. One trial was spoiled by a subsequent frost cutting all the blossom and another by the fact that the grower sprayed the treated trees with a spring wash. The third, however, was left untouched and though the application of the whiting wash was followed by heavy rain almost before it was completely dry the resulting crop was good and equal to trees sprayed with a summer wash only.

The whiting wash, though it gave good results as regards sticking, presented difficulties owing to the large amounts of hot water required. In order to get the starch and glue into solution about half the total quantity of water had to be hot. This was a serious drawback and a way was sought to overcome it. The fact that starch could be jellied by caustic soda seemed to suggest a possible solution. It was found that starch jellied by caustic soda gave the required thickness to a whiting mixture but that at the same time it had no coherence and gave a very thin coat. With lime, however, not only was the mixture well thickened by this process but it also retained its coherence.

The following mixtures were therefore tried. They avoid the use of hot water:

No.	Lime	Glue	Farina	Soda	Dichromate	Water	How made
(1)	2	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{64}$	10	The soda added before straining the mixture. This resulted in too thick a mixture to strain but it was worked through and applied to trees
(2)	2	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{64}$	10	Lime mixed with half full quantity of water mixture, strained and then the soda added
(3)	2	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{16}$	$\frac{1}{64}$	10	Lime mixed with full quantity of water and strained. Soda then added
(4)	2	$\frac{1}{8}$	$\frac{1}{8}$	—	$\frac{1}{64}$	10	Starch jellied by the heat of the freshly strained milk of lime

Of the first three (2) was distinctly the best but (4) proved better than all, having a good thick smooth coat. It showed however some tendency to flake. It is hoped to extend these experiments this season.

Action of lime wash on insect eggs.

It seemed desirable if possible to ascertain the nature of the action of a lime coating on Psylla eggs since it certainly does have some checking action.

To do this, apple twigs abundantly covered with Psylla eggs were cut off the trees in March. These were covered with various washes and placed in a beaker of water till the eggs of the controls hatched. The mixtures tried were

No.	Whiting	Lime	Glue	Water
(1)	6	—	1	10
(2)	—	2	—	10 applied hot
(3)	—	2	—	10 applied cold
(4)	—	1	—	10

On the control twig the Psylla hatched in abundance by April 18. (1) showed only two larvae hatched. On dissolving off the whiting

coat with dilute hydrochloric acid many were found in a dried up state in the egg which had not hatched. Others remained fresh and juicy within the unhatched egg. They appeared normal but failed to hold later on. Only a few eggs had hatched and of these only two had succeeded in reaching the open bud.

(2) None were found in the buds. On dissolving the lime coat by dilute hydrochloric acid many larvae were found to be unhatched but dried up. Others had hatched but had failed to get more than a little way out of the egg shell. Others had succeeded in escaping from the egg but had been killed while traversing the lime coat. Newly hatched larvae placed on a lime-coated slide become completely covered with lime and usually die in about two hours, during which time they only crawl a very short distance.

In a second twig coated with (2) larvae were found fairly abundantly in the buds. In both twigs no fresh apparently normal eggs were found as was the case in the whiting coated twig, and in both cases, on solution of the lime coat, dried up larvae were found in the resultant solution showing that they were actually present, held immovably under it.

(3) Some were found in the buds. Lime flakings treated with dilute acid showed presence of larvae. On treatment with acid the shoot showed large numbers of hatched eggs, also of larvae dried in the egg shell.

(4) Practically none in the buds. After solution of the lime by acid many hatched eggs were found and a few larvae dried in the egg shell. As in all the limed twigs living larvae were found crawling on the lime.

From these experiments it appears that:

(1) A thick covering largely prevented the appearance of larvae in the buds.

(2) The lime coatings largely prevented rupture of the egg shell and where rupture had taken place many had not succeeded in getting out of the shell.

(3) Of those that had, many did not succeed in getting to the surface.

(4) Of those that had succeeded in getting to the surface a good proportion were killed by the powdery lime adhering to their bodies.

(5) The whiting coat almost entirely prevented hatching but did not have such a desiccating action.

(6) Under laboratory conditions a thin wash as lime one to water

ten produced as good a result as a thick, but under outside conditions a thick coat is necessary in order to allow for the eroding power of weather conditions.

In conclusion I have to thank Prof. Barker for much valuable assistance and many suggestions.

Abstract.

A. These experiments were started to find a cover spray which:
(1) Is thicker than ordinary lime wash;
(2) Resists weather conditions;
(3) Is cheap;
(4) Is easily made.

Of these a formula containing whiting, glue, starch, potassium dichromate and water fulfils the first two conditions. It fails in numbers (3) and (4) as its cost works out to 2*d*. a gallon and it is not sufficiently easy to make as so much hot water is required.

B. If lime alone is used:

(1) It must be used when fresh.

(2) It should be allowed, if possible, to stand for 12 hrs. before application. To do this on a large scale, one-third of the total quantity of water may be added first. When it is to be applied, the other two-thirds can be added. This does away with the necessity of having a large number of tubs.

C. The beneficial action of lime wash on Psylla eggs is due to the mechanical, sealing action rather than to any chemical one.

A PRELIMINARY INVESTIGATION AS TO THE CAUSE OF ROTTING OF ORANGES FROM BRAZIL.

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(With 1 Text-figure.)

Hitherto, so far as can be ascertained from literature and men of long connection with Brazilian exports, oranges have not been successfully brought over to this country on a large scale in a saleable condition. The flavour and size of these oranges would make them a valuable asset to our table as they would arrive in this country at a time (July and August) when supplies from other sources are low.

The great problem which confronts us however is to get the oranges over in a sound condition, as hitherto every consignment to this country has been more or less rotten. The port of shipment from Brazil is Rio de Janeiro which is about 18 days sea-passage from London, and, allowing several days for packing, etc., an interval of at least three weeks would elapse before their arrival on the London market.

In beginning investigations it was arranged that a box of 50 oranges should be sent through a large firm of Brazilian fruit-importers to be packed in the following ways:

4 oranges wrapped in tinfoil;
4 covered with thin tissue paper and buried in dry sawdust;
4 in dried banana leaves;
4 in tissue paper and not buried in sawdust;
4 subjected to steam for a few seconds, the excess of water drained off and then wrapped in tissue paper;
The rest unwrapped.

The various lots were placed in separate boxes and these were then put into one large perfectly closed box. This box during shipment was conveyed as ordinary freight and not in the ship's cooling chambers.

When the oranges reached England their condition was as follows:

How packed	No. of oranges	Number wholesome	Number with traces of rottenness or wholly bad
Packed in sawdust and thin paper ..	4	4	0
Packed in tinfoil	4	3	1
Ordinary tissue paper	4	2	2
Steamed and wrapped in tissue paper ..	4	0	4 very bad
In dried banana leaves	4	3	1
Packed without wrapping of any kind ..	30	About 20	10

From the above table it would indicate that the best series were those isolated by thin paper and dry sawdust and the worst those subjected to heat and moisture.

One noticeable feature about the unwrapped oranges was that wherever a diseased orange occurred a large excess of moisture occurred in the same area. This suggested a line of enquiry as to whether moisture might not help in the spread of the disease.

The sound oranges were used for inoculation experiments and the preparation of culture media.

Two fungi were found on the bad oranges; one was the common fungus *Penicillium italicum*, while the other had short colourless hyphae with small black zygospores and appeared to be one of the *Mucorineae*. It was found impossible to isolate the latter but the former was easily isolated and cultivated on a 3 per cent. gelatine medium mixed with orange juice. This orange juice gelatine was used throughout, sterilised in the autoclave. The pure cultures obtained were used for infecting sound oranges, in some cases spores only being used, in others mycelium, and in others mycelium together with a little culture medium. During the time that cultures were being obtained the skin of the orange was investigated and the various tissues met with tested as regards their chemical composition. Externally a fairly thick cuticle occurs, below which is a single layer of cells with cellulose walls forming a very shallow epidermis, and beneath this a many-layered tissue with cellulose walls and variable size of cells forming a many-layered parenchyma, often filled with small granular cell contents and yellow in colour. Embedded in this yellowish tissue are many oil glands which extend in many instances quite up to the epidermis and buried deep in the tissue at the other, the glands being more or less oval in shape and lined with a single layer of epithelium.

Below this glandular layer another many-layered parenchyma occurs with irregular shaped cells with large intercellular spaces and

somewhat fibrous strands intermingled with them, the walls of this open tissue being of cellulose, similar to that of closed tissue.

Dusting spores on the uninjured skin, laying on mycelium or putting on mycelium together with gelatine medium, it was found impossible to induce the fungus to attack the orange so long as the cuticle of the skin was undamaged, but if the cuticle was pierced with a sterilised needle or small pieces of it were removed with a razor, then the fungus soon attacked the underlying parts of the skin surrounding the oil glands or between the oil glands and the cuticle.

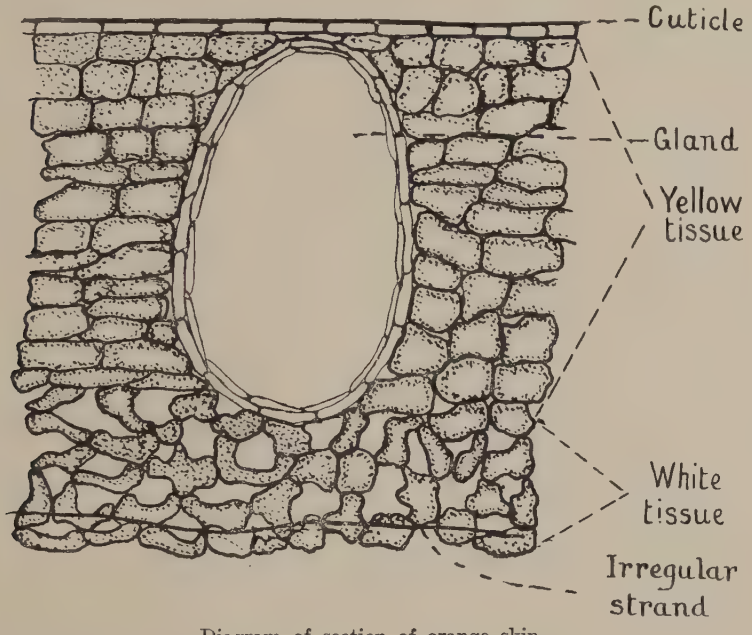

Diagram of section of orange skin.

The first symptom of attack is a brown coloration in the region of infection, which soon spreads in all directions under the cuticle.

Later on the white mycelium of the *Penicillium* appears and follows in the wake of the coloured tissue, and as the discoloration of the tissues continues so the *Penicillium* spreads at the same rate.

On examining this brown tissue no fungal hyphae could be found and it appears that when the fungus gains an entrance into a host it pours out an enzyme which acts on the tissues in the neighbourhood causing them to change colour. This change occurs first in the cell contents and later the cell walls break down.

This brown area preceding the *Penicillium* on the orange also occurs on orange gelatine cultures.

Another change that is undergone by the skin during attack is, that in a sound unaffected orange it is impossible to strip off the cuticle, which can only be removed by cutting the underlying tissues, but when the fungus gets in the cuticle can easily be removed from any of the coloured areas with forceps without any cutting whatsoever. When the attack has become very bad the whole of the cuticle of the orange can be stripped off.

No trace of the fungus piercing the cuticle could be found, although hanging drop cultures of cuticle and fungus were taken.

When the attack is very bad the part of the skin below the cuticle becomes a soft sticky mass, which sooner or later pours out a yellow oily liquid on to the soft surface of the skin together with a large amount of water.

When the orange became soft and pulpy it was noticed that large numbers of small flies appeared on the orange and remained so long as the orange kept its normal shape, but when it completely collapsed the numbers decreased.

It was found impossible to infect a sound orange by leaving it in a vessel with a badly diseased one even in contact with it, but the pouring out of moisture by the diseased one caused the sound one to become covered with moisture and in this way many more spores would adhere to it than would otherwise have taken place and in this way would have a greater chance of finding any slight puncture in the cuticle.

Leaving a sound orange standing in a shallow dish of water the wet portion becomes soft and discoloured and then the cuticle can easily be removed and the tissues attacked with *Penicillium* when removed from the water, but the dry portions out of the water were never attacked unless a previous puncture of the cuticle had taken place.

From these few simple experiments it would appear that the most promising way of sending oranges is that they be kept as dry as possible and in picking and packing care being taken to prevent the cuticle becoming damaged in any way.

Experiments were tried with various chemicals. Solutions of 2 per cent. copper sulphate and 5 per cent. formalin were used on the cut surface of the orange skin and were found to be more or less effective, for if spores were sown on the cut areas the fungicide appeared to check their growth.

The question arises, "Can the oranges be safeguarded from fungal attacks by immersion in some fungicide, or if the spores have already settled in some slight wound can their action be stopped?" Further trials are necessary to solve the problem but the first trials on an extensive scale seem to indicate that *Penicillium italicum* can be checked, but in its stead rottenness due to some other cause sets in; for the first box of oranges sent to me treated with formalin before packing and then packed in dry sawdust, of the three hundred it contained not more than six were sound the rest all being bad, with not the slightest trace of *Penicillium* on them: the cause of rotting appears so far as can be made out on preliminary inspection to cause the fruit to become perfectly brown and somewhat wrinkled, losing their orange shape, the cuticle remains tough and does not come off easily, while the parts of the skin below it are perfectly brown, and suggest a new line of inquiry which I hope to conduct in the near future as further boxes are sent over treated in various ways.

In conclusion I should like to acknowledge my indebtedness to W. Austin, Esq., of London for the trouble he has taken to get the oranges over and to see that instructions were as far as possible carried out to ensure correct information being obtained.

EFFECTS PRODUCED BY SUCKING INSECTS AND RED SPIDER UPON POTATO FOLIAGE.

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(Plates XXIII—XXVII.)

A series of experiments is here described which was designed to ascertain accurately what effects are produced in potato foliage by the action of sucking insects.

The potato plants used were seedlings of the President variety, a variety particularly subject to the curl disease. The first seedlings were raised at Chelsea in 1911 and subsequent series of plants at Chelsea, Wisley and at Messrs Sutton's trial grounds. The greater number were raised at Wisley, 1912–1914, nearly a thousand plants in all.

The raising of these plants from seed, their variability and behaviour under different conditions of growth, and experiments with them not directly concerned with this present work will be described elsewhere.

The objects we hoped to attain and succeeded in attaining were firstly, to be in a position to assign definite symptoms to certain insects and so to be able to eliminate them at once if one is seeking effects produced by fungi or bacteria, as, for example, in the curl disease where pathological symptoms such as dwarfing, yellowness, blotching and dead leaf ends occur; and, secondly, the application of this knowledge in seeking the distribution of pathological conditions due to insects in the field.

A result of this work was the investigation of the mechanism of sucking in two of the species concerned, in *Lygus* by P. R. Awati (*Proc. Zool. Soc.* September 1914) and in *Aleurodes* by E. Hargreaves (*Ann. App. Biol.* I. Nos. 3 and 4).

Infestations.

The following species were used in making infestations:

1. *Aleurodes vaporariorum* Westd.
2. Red Spider, *Tetranychus telarius* Linn.
3. Aphis, *Rhopalosiphum solani* Theob.
4. Jassid, *Eupteryx atropunctata* Goeze.
   Chlorita viridula Fall (? *C. solani* Koll.).
5. Capsid, *Calocoris bipunctatus* Fabr.
   Lygus pabulinus Linn.

The first three of these, being obtainable early in the year, were used for the first series of infestations, commenced at Wisley on March 22, 1912. Jassids and Capsids were not obtainable until June, hence infestations with these insects were not commenced until after the earlier experiments were completed. Parallel infestations, using the above-mentioned insects, were carried out at Chelsea upon the plants raised at Chelsea.

The conditions under which the experiments with Aleurodes, Red Spider, and Aphis were carried out were as follows: The floor of the greenhouse adjoining the laboratory at Wisley was covered with a layer of garden soil and a number of cloches arranged in rows upon it. Some of the cloches rested directly on the surface of the soil. Under these conditions, if the soil were regularly watered, the atmosphere within the cloches would remain saturated. The remaining cloches were raised above the level of the soil supported on inverted pots so that the air inside the cloche was in communication with the air outside but would be on the whole damper than that of the greenhouse and sometimes saturated.

Four pots were placed under each cloche. Groups of four plants not covered by a cloche were also stationed on the soil.

The experiments arranged at Wisley were as follows:

No. 2. Red Spider. Cloche on inverted pots. Plants watered seldom.

No. 1. Aleurodes. Cloche on inverted pots. Muslin edging to prevent escape of insects. Plants watered regularly.

No. 9. Aleurodes. Cloche on soil. Plants watered regularly.

No. 4. Aphis. Cloche on inverted pots. Plants watered regularly.

No. 3. Aphis. Cloche on soil. Plants watered regularly.

No. 5. Aphis. Plants not under a cloche. Watered regularly.

No. 6. Control. To plants placed under cloches resting on inverted pots.

No. 7. Control. To plants placed under cloches resting on the soil.

No. 8. Control. To plants not under cloches.

No. 10. Control. Pots placed in a vessel containing water, and a cloche inverted over the whole so that the atmosphere remained constantly saturated.

The plants used for the infestations had been uniformly treated, and we selected as far as possible plants of a similar character and equal amount of growth.

Effect on the plants of the conditions under which they were placed.

The plants grown under the cloches soon differed from those not covered at all and the difference was most marked in the case of the plants grown in an enclosed atmosphere. In a constantly saturated atmosphere the plants became larger but procumbent, and developed larger but thinner leaves than the uncovered control (Fig. 1). The plants under cloches resting on inverted pots were less changed.

Several of the plants responded to the experimental conditions by the development of intumescences on the leaves. This feature was more marked in the case of the plants grown under cloches placed directly on the soil.

Red Spider.

No. 2. Four pots, on soil, under a bell-jar raised on inverted pots.

22. 3. 12. Put in leaves of Rhynchosia with many red spider on; the leaves laid between the pots so as not to touch the plants or shade them.

5. 4. 12. Abundant red spider on the plants. The symptoms produced were:

cessation of growth;
yellowing of the leaves;
many minute discoloured spots, giving the leaf a speckled, brownish appearance;
eventual drying and browning of the plants, which die.

No curling was produced at any time.

One of the plants was photographed on three occasions—April 5, 13 and 17—to show the progress of the infestation. (See Figs. 2, 3, 4.) The experiment was repeated, using leaves from the plants already killed by red spider, with similar results.

It was observed that the plants did not all succumb to the attack at the same time although the chances of being infested were equal.

Aleurodes. Fig. 5.

No. 1. 22. 3. 12. Four pots were placed on soil under a bell-jar raised on inverted pots; 20 flies from Salvia and 24 from potato were liberated under the jar, some escaping.

5. 4. 12. Eggs seen on the leaves; the plants were clean, healthy and similar in appearance.

17. 4. 12. Scale first observed.

24. 4. 12. Young flies observed.

5. 5. 12. Many scales on the leaves, a few empty, the first flies having emerged. There are no symptoms to record; the leaves are not spotted nor noticeably yellow. The control plants, grown under similar conditions but without insects, do not differ from the infested plants.

No. 9. 23. 3. 12. Four pots on soil, under bell-jar raised on inverted pots, with a double muslin curtain containing soil round the lower part of the jar and resting on the soil. Sixty-seven flies from Salvia were liberated.

5. 4. 12. Many eggs on the leaves, some dark, some yellow. Two dead flies seen with a cloud of white threads (? hyphae of a mould). Photographed 9 o'clock.

5. 5. 12. Good infestation of scales. The leaves are slightly yellow as compared with the control kept under similar conditions. There are no other observable symptoms and the leaves are clean, not curled, and well grown.

All the plants infested with Aleurodes were kept free from Red Spider and Aphides.

Experiments set up out of doors were unsuccessful because the plants were killed by frost.

Aleurodes. Gross infestation.

During the course of the experiments described above, the whole of the plants raised at Wisley from the January sowing, and not used for the infestations with individuals, had been kept in a cool frame arranged in series according to the method of potting, kind of soil and origin of the seed. Aleurodes soon appeared amongst them and was allowed to increase unchecked. All the plants were examined critically, one by one, on May 8, and there was noted by one observer the amount of Aleurodes and Aphis, and by the other the characters of the plants themselves, for example, height, whether upright or procumbent, size and shape of juvenile and adult leaves, and the presence or absence of blemishes, such as blotches, pinkness, discoloured veins, yellowness, etc.

The first three series, potted in coarse soil, in large pots, will be considered together since no attempt is here made to draw deductions

between them, but only between the individuals composing a particular series. The series comprise:

Series I. Plants raised from seed obtained from both good and bad plants, Edinburgh.

Series II. Plants raised from seed obtained from good plants, Dunbar.

Series III. Plants raised from seed obtained from bad plants, Dunbar.

The distribution of Aleurodes is shown below.

Distribution of Aleurodes. Series I—III.

	No. of plants in series			
	I	II	III	Total
With eggs, scale and imago	1	1	2	4
„ „ and imago	3	2	4	9
„ „ „ scale	1	1	4	6
„ „ only	4	2	1	7
„ scale „	5	4	5	14
„ imago „	0	3	1	4
Without eggs, scale and imago	8	4	6	18
Total	22	17	23	62

There is not any very marked difference between the three series and we may look at the whole 62 plants together:

There are 18 with no Aleurodes in any stage,

Nine in which eggs and flies are abundant, scale few,

Fourteen in which scale is abundant only,

Six in which both scale and eggs are both noticeable.

Without unduly straining the figures we may say that the plants have been unequally selected by the flies of each brood and that there is a very high percentage (29) of plants that have been avoided: is this selection correlated with any plant character that can be noted?

We have been unable to find any character of the plants which we can correlate with the presence or absence of either the scale form or the eggs: clearly there is a connection between the presence of Aphis and the discoloration of the veins: there is no connection between the blotching and the presence of either Aphis or Aleurodes; and there is not any character that we could note which is correlated with a marked presence or absence of either the scale form of Aleurodes or its eggs. It has been possible to note only certain physical characters: it is possible that there is a character connected with the condition of the leaf surface, or the texture of the leaf, or the composition of the cell substance or sap

which does determine whether the fly lays eggs on a plant or not: we believe that there must be some such character which is not revealed by the physical characters that we can note. Had there been a marked difference between the character of the foliage in Series I—III we could perhaps have found some such character as is discussed in Series III, but there is not sufficient difference in this respect to make it discernible.

Series IV.

Plants from seed from Edinburgh and Dunbar, still in small pots. These are markedly less infested and it was possible only to note them as having either no scale at all, scale numbering from one to ten or scale clearly exceeding ten on the whole plant.

Edinburgh:
- Clean 20
- Under ten 18
- Over ten 16.

Dunbar, seed from healthy plants:
- Clean 17
- Under ten 8
- Over ten 5.

Dunbar, seed from diseased plants:
- Clean 10
- Under ten 11
- Over ten 2.

Total:
- Clean 47
- Under ten 37
- Over ten 23.

In this series also there is uneven distribution of Aleurodes and, seeing that these plants had been kept side by side with the series in larger pots which are more infested, it was suggested that the fly selected for egg-laying those plants with more foliage or with healthy foliage not likely to fall off. The plants as classed above for amount of Aleurodes were then grouped according to the amount and condition of their foliage, the resulting figures being:

Clean plants	Bad foliage	23	Good foliage	21
Under ten plants	„ „	12	„ „	24
Over ten plants	„ „	4	„ „	19

These figures point, not very decisively, to the fly selecting for egg-laying those plants with more leaves and more perfect ones; this may mean (1) the fly prefers itself to repose on such foliage, (2) it prefers to feed on such foliage, or (3) it definitely selects such foliage for egg-laying on. On this point we can only say that there is a fair concurrence of plants on which flies were found as well as eggs: that is that the plants on which the flies sit and feed are also those on which they lay eggs (see Series I—III). It is noteworthy that there is very much less scale on the far smaller plants of Series IV than of Series I—III, though they were throughout kept together; there is no plant in Series IV which in Series I—III would have been marked as more than "scale moderate." This may be due to the Series I—III plants being in higher pots and so nearer the light or to their greater amount of foliage.

It seems to be quite clear that there is a definite selection of plants by the Aleurodes which may be connected partly with foliage but must also depend upon some other character that we cannot determine.

Aphis. Figs. 6, 7.

No. 3. Four pots on soil under bell-jar placed on the soil.

22. 3. 12. Placed twelve Aphides on each plant. These were of varied size, including in each case two winged forms, and were taken from potato plants growing in pots.

26. 3. 12. Intumescences observed in the plants.

1. 4. 12. Some leaves with discoloured veins.

2. 4. 12. The Aphides were counted, being 43, 14, 6, 16 respectively on the four plants.

5. 5. 12. One Aphis found on each plant.

No. 4. Four pots under a bell-jar which is raised on inverted pots leaving a space between the jar and the soil. Put in Aphides from the potato plant on 22. 3. 12.

1. 4. 12. The Aphides total 97, 40, 19, 54 on the respective plants.
Some leaves with discoloured veins.

5. 5. 12. A heavy infestation, the most Aphides on the lower surface of the lowest leaves. The symptoms noted are:

yellowing of the leaf generally;
the veins on the lower surface become dark coloured;
the leaf tips and margins become brown, dry and brittle;
the leaf eventually falls off.

No. 5. 22. 3. 12. Four pots uncovered, each infested with 12 Aphides from a potato plant.

1. 4. 12. Several leaves with discoloured veins in all the plants.

2. 4. 12. Aphides on plants number 46, 89, 108, 103 respectively.

5. 5. 12. Three plants very heavily infested, one not. Of the infested ones, one is withering, the leaves limp, yellow, curling and browning at the tips, the veins dark; two have the leaves yellow, the veins dark, the tips brown. The plant now free had the veins heavily dark, the leaves browning off from the tip.

Since the plants of No. 5 were not confined, they became infested with Aleurodes which was present in the greenhouse. The flies were continually removed to the extent that scale was present on only one plant on April 19.

A comparison with the controls shows that these symptoms were undoubtedly due to Aphis. The plant under Cloche 7, control to Aphis 3 (plant enclosed), did not develop discoloured veins (Fig. 8), either on the leaves present at the time of the infestation or on the leaves newly formed whilst under the cloche. The plants under Cloche 6, control to Aphis 4, were with difficulty kept free. On April 2, 106 were removed, 48, 8, 40 and 12 respectively on the four plants, and the veins of some leaves on the third and fourth plants were slightly discoloured. The plants under Cloche 8, control to Cloche 5, were not enclosed and hence exposed to repeated infestation. The Aphides were frequently removed, 53 were removed on April 2 and the veins were not discoloured, but soon a relative difference only could be observed between the infested and control plants and the two sets soon became equally and heavily infested.

From the above results it will be seen that the earliest symptoms due to Aphis show themselves on the leaves, the midrib and veins of which become brown, and that these symptoms appear, irrespective of the conditions under which the infested plants were placed, within ten days from the date of infestation.

The further progress of the infestation and the development of later symptoms were, however, influenced by the conditions under which the plants and Aphides were kept. On April 1, the distribution of Aphides was as follows: Cloche 3, 79; Cloche 4, 210; Cloche 5, 346; a result showing that the Aphides multiplied most on the plants not confined, least on the plants entirely enclosed. In fact they gradually decreased in number on the enclosed plants until on May 5th only four remained.

The symptoms rapidly increased on the plants not enclosed, the leaves becoming yellow, the veins dark brown, and the leaf tip curled, brown and dead.

Gross Infestation by Aphis. Chelsea.

The Chelsea plants were examined by one observer on May 17 and their characters noted. They were very different in appearance from those raised at Wisley, being on the whole taller with more slender stems and the leaves much smaller. No less than nine plants had developed two or more slender stems instead of one, thus greatly modifying the general appearance. The characters yellowness, pinkness, and blotch, characteristic of the Wisley series, were entirely absent, but five plants possessed hooded or curled leaves—the margin bent downwards—a character absent from the Wisley plants. No insects were observed upon the plants on May 17th.

The plants were examined critically by the other observer for insect characters on June 11. These had been free of all insects except Aphis, which had been allowed to increase on the plants for three weeks unchecked, the plants then being evenly and lightly infested. The plants were examined individually and the points noted for each (as these proved to be the same throughout it is not necessary to reproduce them in full). The following points should be noted:

All the plants had colonies of Aphis on the large old leaves. Leaves lightly infested showed no definite symptoms: darkening of the veins occurred in all cases of more than light infestation and the oldest leaves also showed marked yellowness, not necessarily due to Aphis.

In cases of severe infestation the tip and edges were brown. Old broad leaves were not quite flat but curved: curling was not seen. Small leaves were in many cases sharply curled, but this symptom was not coincident with the presence of Aphis nor with the occurrence of dark veins. Aphis was present in many cases on the small leaves, but on picking out all plants with curled leaves these were not markedly infested with Aphis on the small leaves.

There is no evidence of Aphis selecting plants; all had Aphis on now or had signs of previous occurrence of Aphis.

Gross infestation by Aphis. Wisley.

A series of seedlings raised later than Series I—IV was examined for Aphis on July 24. On this occasion there were three plants with curled leaves and Aphis was absent from two of them.

A series of 80 plants raised from the original stock of seed, in 1914, and exposed to infestation yielded a somewhat different result. Thirteen plants exhibited hooded or curled leaves and all were infested

with Aphis. The youngest leaves were chiefly affected and infested, but in this case they were often considerably distorted and their veins discoloured.

Jassid series. (A) Wisley.

1. June 5. Three plants were infested with 10, 9 and 9 Jassids respectively, Eupteryx species and a green species.

June 8. Small white spots were present in the infested plants but absent on the controls (Fig. 9).

The spots are about 1 mm. in diameter and possess an irregular outline. When a number occur close together, whitish blotches or patches are formed, more usually on the upper surface of the leaf. The spots are not confined to the young leaves and do not occur in sufficient number to cause the death of the leaf directly. The tissue of the leaf is not lacerated as in the case of injuries caused by Capsids. The epidermis is punctured and the proboscis of the insect injures and destroys the chlorenchyma. The white appearance of the spot or blotch is due to the loss of chlorophyll and perhaps an optical effect, in part, due to included air.

2. June 11, 3 p.m. Single plants infested with one Eupteryx collected at Wisley.

June 12, 10.30 a.m. White spots present on one leaf. Eupteryx still alive. The spots have been produced within 20 hours.

Jassid series. (B) Chelsea.

June 9. Put three clean plants under a bell-jar with two winged *Eupteryx atropunctata*. Controls all clean plants unspotted.

June 11. Removed the bell-jar and the two bugs; observed small light spots on several leaves; controls not spotted.

June 13. The spots are slightly brown.

June 20. The spots are larger and in some cases have become holes.

Capsid series. (A) Wisley (Fig. 10).

1. June 12. Put one clean plant under cloche with four wingless green Capsids collected at Wisley.

June 13. Small brown spots observed on youngest leaves.

2. June 12. Put one clean plant under cloche with two green winged Capsids collected at Wisley.

June 13. The following symptoms had developed:

black stripe along petiole;

dark blotch on leaf lamina;

young leaves with dark brown irregular blotches on the upper surface.

3. June 12. Put one clean plant under cloche with two brown winged Capsids collected at Wisley.

June 13. No visible result.

4. June 12. Put one clean plant under cloche with three small green and brown grass Capsids.

June 13. No visible result.

5. June 12. Put one clean plant under cloche with one striped nymph off grass.

June 13. No visible result.

6. June 14. Put one clean plant under cloche with three Capsids collected at Wisley.

June 15. No visible result.

June 17. Youngest leaves with brown blotches.

7. June 14. Put one clean plant under cloche with nine Capsids collected at Oxshott.

June 15. Small brown spots appeared on the youngest leaves.

June 17. Attack severe. All the youngest leaves spotted and blotched and nearly dead. Six Capsids were observed.

8. June 14. Put one clean plant under cloche with one Capsid collected at Oxshott.

June 17. No visible result.

Capsid series. (B) Chelsea.

1. June 11. Put three clean plants under a bell-jar with one green winged Capsid and one green nymph in the last stage, both collected at Wisley that day.

June 13. No visible result. Added two green nymphs from Walton.

June 20. One plant has the small foliage with holes edged with brown. Another plant has two leaves the same. The third plant shows nothing.

2. June 11. Put two clean plants under a bell-jar with ten unwinged green Capsid nymphs, collected that day on potato plants at Wisley.

June 13. No visible results. One winged form, the rest nymphs.

June 20. The small leading shoots are brown and dead. The smaller leaves have holes edged with brown.

No control shows these symptoms at all; apparently the Capsids feed on the shoots and youngest leaves and give rise to holes in the leaves and to the death and browning of the apical shoots. This effect has not occurred on any plant at Chelsea except those infested with Capsids. (The action of Eupteryx on the leaves is exactly the same as that at Wisley.)

Capsid symptoms.

In these experiments the insects attacked the youngest leaves and small irregular spots or blotches were formed which were either scattered or so numerous as to give the leaf or leaflet a brownish appearance. Each spot when first formed possesses a clear centre with a brownish boundary. The spots are due to the laceration and destruction of the tissue at the places where the insects feed—either on the upper or lower surface (usually the latter) of the leaf. Small pits are formed which often extend to the opposite epidermis and the leaf may be perforated or if not, perforation soon takes place. The dark boundary to the spot is evidently due to the discoloration of the broken cells which form the wall of the pit. Veins near the pit are lacerated, discoloured and sometimes severed. When the attack is severe, the chief veins of the young

leaves are partly severed, so that the leaf or leaflet soon withers and dies. In severe cases the young shoot dies.

The discoloration of the veins caused by Capsids occurs rapidly after the infestation and discoloured veins are associated with the presence of lacerated pits or areas. Discoloured veins due to Aphis develop after several days have elapsed since the infestation and they are not associated with lacerated tissue.

The difference in symptoms produced by the Capsid and Jassid is accounted for by different structure of the stylets of the mouthparts. P. R. Awati (*Proc. Zool. Soc.* 1914, p. 685) figures the mouthparts of *Lygus* and shows that the outer pair of stylets (the mandibles) are barbed; when they are withdrawn the plant tissue is lacerated. In the case of *Eupteryx*, the outer stylets are smooth and they can be withdrawn without further injury than that caused by the sucking.

The mechanism in *Aleurodes* is described in another paper above by Hargreaves, but further work is required to compare the action on the plant-tissue of the sucking mechanisms of *Lygus*, *Eupteryx*, *Rhopalosiphum* and *Aleurodes* respectively. The actual structure of the mechanism is not sufficient; we are ignorant of the action inside the plant.

Field observations.

We are enabled to report upon insect injuries to potato foliage at the following places:

1.	Barley (Herts).	Potato breeding experiments by Dr Redcliffe N. Salaman.
2.	Brentford.	Private garden.
3.	Chelsea.	Experimental plots at the Physic Garden.
4.	Dunbar.	Field crop.
5.	Edinburgh.	Field crop.
6.	East Lothian.	Field crop.
7.	Midhurst (Kent).	From specimen.
8.	Oxshott.	Private garden.
9.	Reading.	Messrs Sutton's trial grounds.
10.	Strawberry Hill.	Private garden.
11.	Walton-on-Thames.	Market garden.
12.	Wisley.	Trial and experimental plots.
13.	Woking.	From specimens.
14.	Wye (Kent).	Experimental plots.

Field observations on Aphides.

Aphides were very closely under observation at Wisley in 1912. On July 5 it was found that some varieties were badly infested and others not at all. These Aphides were not observed on the Duke of York; a few were found on Arduthie Early and Ringleader, associated with discoloured veins, whilst there occurred among a single row of Sharpe's Express, twelve plants with dead foliage, eight with foliage undoubtedly killed by Aphides and six with foliage still green. In several cases the original injuries caused by Aphides had received secondary extension owing to a period of wet weather—the portion of the leaf-blade next the discoloured mid-rib first decayed, the decay spread and ultimately involved the whole leaflet. In spite of the presence of numerous Coccinellids, the Aphides appear to have got the upper hand.

Certain varieties grown in another part of the Wisley Garden and including the Duke of York, the Sutton Flourball, Up-to-Date, Langworthy, Northern Star and President were scarcely affected by Aphides, although these were present throughout the season. Coccinella was abundant here also but appears to have held the Green fly in check.

Diseased plants received at the Wisley Gardens from Woking on July 2, 1912, were stated by the sender to have stopped growing at quite an early stage, and bore only six tubers of very small size. The plants showed similar symptoms to those which appeared on the Sharpe's Express variety at Wisley—discoloured veins and a secondary extension owing to bad weather. Living Aphides were present on the specimens and the disease was certainly caused by them.

Similar specimens with remains of Aphides upon them were received from Midhurst on July 6. The sender had been advised that owing to disease in the haulms, potatoes should not be grown on the same ground for two years. The haulms were not diseased, the condition of the plants being again due to Aphides.

Owing to the kindness of Dr Redcliffe N. Salaman we were enabled to study the experimental races of potatoes raised by him at Barley in 1911 and 1912. It was observed in 1911 that the foliage of certain races was badly diseased, whilst the foliage of other races remained almost entirely healthy. The chief symptoms of disease took the form of brown blotches, dead leaflet-ends, and perforations, but no attempt was made to ascertain the cause of these symptoms then.

In the following year there was a recurrence of the phenomena already mentioned, whilst again certain races remained quite healthy; nevertheless, the foliage of almost every plant of other races was badly diseased. The whole question of the disease in the foliage at Barley cannot be discussed here, since it must be considered in relation to all the conditions under which the races in question were raised and grown. Three types of injury could be distinguished:

1. Blotched foliage not associated with discoloured veins, neither insects nor their remains present.

2. Badly blotched foliage associated with discoloured veins and Aphides.

3. Blotched foliage associated with the presence of Capsids.

A great deal of the damage was certainly due to a secondary extension of the injuries primarily caused by insects, owing to a period of bad weather following the infestation. Coccinella was not present in abundance.

By kind permission of Messrs Sutton, the firm's potato trials at Reading were visited in 1912. The plants were remarkably free from blemishes of any kind and on several varieties, notably Garden Favourite and Maincrop, no injuries due to insects could be detected at all. Amongst plants of Windsor Castle only one was infested with Aphis. Several plants of the Up-to-Date had been attacked and showed the characteristic brown veins. Curiously enough the Up-to-Dates were adjacent to other varieties from which insect injuries were absent. Coccinella was abundant.

Field observations on Capsids.

The President plants grown at Wye in 1911 were practically free from insect injuries, but they were also free from blotches or discoloured veins. On July 30, 1912, Professor Theobald informed us that he had observed nothing but a few Aptera and some Capsids on potato plants at Wye in that year.

The plants raised at the Chelsea Physic Garden in 1911 were badly blotched and it is now quite clear that the condition of the foliage was due to Capsids. On June 28, 1912, the plants grown from tubers in the open at Chelsea were more carefully examined for insects. Several plants had been injured by Capsids and many Capsids were observed.

The first Capsids used for experimental purposes were captured at Wisley on June 11, 1912. This was almost their earliest appearance at Wisley. On June 17 Capsids were active at Oxshott, especially on

the Duke of York variety. They blotched and killed many of the young leaflets and young shoots.

Soon after the appearance of Capsids at Wisley a large market-garden at Walton-on-Thames was visited. Here the foliage of a great number of plants exhibited blotching in some form or another, but the marks could not be attributed to the agency of insects nor fungi. Capsids were observed only on the Eclipse and at this early date had caused but little damage.

Capsids were in abundance at Reading on July 3 among plants of the Up-to-Date, and the foliage of several plants was badly blotched. Varieties adjacent to the Up-to-Dates appeared to be quite free from these insects.

Capsids were occasionally abundant during June and July 1912 at Wisley. Brown spots due to Capsids were especially noted on Arduthie Early and a few plants of the Duke of York.

Brown spots due to Capsids were observed on potatoes near Cobham on July 15.

Capsids were responsible for some of the damage observed at Barley in July 1912. Many blotches had been recently caused by these insects, other markings were secondary extensions from blotches formed prior to the wet weather. Many young Capsids were found amongst the plants in question.

At Brentford the action of Capsids generally on potato and other plants was followed during 1913 and 1914. In both years the same sequence occurred: red currant (Fig. 11) was first heavily attacked and the foliage very much destroyed during April—May; then the Capsids went to mallow, cherry (Fig. 12), some other weeds and potato (Fig. 13); the potatoes developed quite normal signs of attack; the bugs then went to Jerusalem artichoke (*Helianthemum*). The life-history has not been worked out in detail, but the sequence of young and adults suggests three broods a year.

The symptoms described above as produced by *Lygus* and *Calocoris* under control are easily discernible in the field and a little searching reveals the nymph or imago of one of the common species.

Field observations have been directed only to determining how far these bugs are definitely associated with symptoms on potato foliage. We think that the bugs deserve far more attention as general garden pests and that far more damage is being done than is generally supposed. This is, of course, no new observation. Theobald (*Ent. Mo. Mag.* 1896, p. 60; *Journ. Bd. Agric.* London, 1909, p. 568) has drawn attention to

Calocoris fulvo-maculatus de G. Carpenter (*Report* for 1896) refers to *C. bipunctatus* F. and to *Lygus pabulinus* L. (*Report* for 1911). Theobald also refers to *L. pratensis* L. (*Report* for 1904, p. 63) and there are a number of references to these species by continental authors. So far as we are aware, these describe attacks observed in the field, not symptoms definitely produced experimentally.

Field observations on Jassids.

Potato foliage was marked with white spots caused by Jassids in many localities in 1912, and these insects were in every case observed in the leaves. The spots were usually scattered and infrequently united to form moderately large areas, and did not involve the whole leaf surface, giving it a whitish appearance, as may frequently happen in the case of the rose and various fruit trees.

The very characteristic white spots can be seen in the field on potato at once and *Eupteryx* is in all cases found there. Similar spotting can be seen on rose, plum, cherry (Fig. 14) and apple in the early stages of Jassid attack, but in 1913, 1914 the attacks became so severe that the whole leaf became yellow.

Such attacks are well known in England and have been described by Theobald and by Curtis.

Summary.

1. Definite and similar symptoms apart from any other cause were obtained as the result of infesting young plants raised from seed of the President variety of potato with Red Spider, Aleurodes, Aphis, Jassid, and Capsid under various experimental conditions at Wisley and Chelsea as follows:

(*a*) Red Spider.—Leaves became mottled, plant turns brown and dies.

(*b*) Aleurodes.—Effect gradual, plants weakened but did not die.

(*c*) Aphis.—Leaves with discoloured veins, brown and dead leaf-ends, yellowing and death of the plant.

(*d*) Jassid.—White spots, plants did not die.

(*e*) Capsid.—Dark brown blotches on leaves and young growth, veins darken, young leaves and shoots killed rapidly.

These symptoms did not develop in the controls except in the cases where the control plant became infested by the particular insect experimented with.

2. The effect on the foliage tissue in each case is as follows:

(*a*) Red Spider.—Epidermal and sub-epidermal cells injured.

(*b*) Aleurodes.—Conducting tissue tapped, not followed by vein discoloration.

(*c*) Aphis.—Conducting tissue tapped followed by vein discoloration after nine or ten days.

(*d*) Jassid.—Epidermis punctured, assimilatory tissue destroyed.

(*e*) Capsid.—Tissue lacerated causing severance of the veins and leaving ragged, irregular pits which become rapidly discoloured as do the veins also within two days.

3. The markings caused by Jassids and Capsids proved distinctive and could be recognised as such for some time after the injury, but for the safe recognition of Aphis injuries the association of typical markings with Aphides or their remains is necessary.

4. Evidence has been obtained that Aleurodes select plants.

5. Definite symptoms due to Aphis, Jassid and Capsid, correlated with the presence or remains of these insects, have been found in the field crops in several districts in three consecutive seasons. During and after periods of wet weather the original injuries, especially those caused by Aphis and Capsid, frequently obtain secondary extension, and the foliage is prematurely destroyed.

6. From field observations Aphides appear to exhibit a preference for certain varieties or races of potato, but the question of selection has not been experimentally studied by us.

Fig. 1. Plant in saturated atmosphere (left) and in the open (right).

Fig. 2. Early Red Spider attack.

Fig. 3. More advanced Red Spider attack.

Fig. 4. Last stage of Red Spider attack.

Fig. 5. Aleurodes adults on plant.

Fig. 6. Aphis on underside of leaves.

Fig. 7. Result of Aphis attack. Note black veins on lowest leaf.

Fig. 8. Control plants to Figs. 6 and 7.

Fig. 9. Results of Jassid attack.

Fig. 10. Capsid attack.

Fig. 11. Red Currant shoots injured by Capsids.

Fig. 12. Cherry leaf injured by Capsids.

Fig. 13. Potato foliage injured by Capsids.

Fig. 14. Cherry leaf injured by Jassids.

NOTES.

The Association.

A MEETING of the Association has not been held since July and the number of members who attended that meeting was not large. A circular was sent to all members in the United Kingdom asking if they would attend a meeting in September: replies were received from about a quarter and only one member was prepared to attend. The meeting was postponed for other reasons.

With this issue we complete the first volume of the *Annals*, the material for the third and fourth numbers being issued as a single part. This has been rendered necessary by events over which we have no control and it is hoped that the first part of the second volume will be issued by the end of March.

Two features of this issue are of special interest. We welcome the papers by Dr Barber and Mr Anstead dealing with problems of tropical agriculture, and we hope to receive many more contributions from members in the tropics. The second feature is the number of shorter articles and notes, dealing with a wide range of topics. Members will assist the *Annals* specially by contributing such short articles and notes.

We include in this issue a review; the publication of critical reviews of important new books should become a feature of the *Annals*. Volumes for review should be sent to the editor, who will send them on to the member of the Editorial Committee concerned.

The *Annals* are sent in exchange to a number of biological publications. Members of the Association can consult the journals received in exchange at the Association's Library in the Royal College of Science, South Kensington. The following are received:

Annales du Service des Epiphyties, Paris: *Bollettino del Laboratorio di Zoologia*, Portici: *Journal of Agricultural Science*, Cambridge: *Quarterly Journal of Forestry*, Oxford: *Redia*, Firenze: *Journal of the Royal Horticultural Society*, Westminster:

Transactions of the Royal Scottish Arboricultural Society: *Bulletin of Entomological Research*, S. Kensington: *Review of Applied Entomology*, S. Kensington: *Tydschrift voor Pflanzenziekten*, Wageningen: *Monthly Bulletin* and *Bulletin Bibliographique*, International Institute of Agriculture, Rome: Publications of the United States Dept. of Agriculture: *West Indian Bulletin*, Barbados: *Agricultural News*, Barbados: *Agricultural Journal of India*, Pusa: *Memoirs of the Agricultural Dept.*, Pusa: *Bulletin of the Agricultural Dept.*, Trinidad: *Bulletins of the Indian Tea Association*, Calcutta: *Gardens Bulletin*, Straits Settlement.

We shall be glad to consider other exchanges and members will find it useful to know that they can consult current numbers of these publications in London.

The library has been added to by the gift of many separates and other publications by members; there is room for much more and members attention is again directed to this. We are laying the foundation of the future library of Applied Biology and if members will co-operate the library will presently be of real value to all workers.

H. M. L.

AMERICAN GOOSEBERRY MILDEW.

At the last meeting of the Economic Biologists Association, Mr Salmon read a paper on some observations on the "Life History of the American Gooseberry Mildew" in which the theory was advanced that the over wintered perithecia of the fungus that remain on the bushes were sterile and could not reproduce the disease in the following season.

Shortly after the paper was read, viz. 24th April 1914, shoots badly affected with the mildew were collected in Kent by one of the Board's sub-inspectors. They were submitted to Kew with a request that they should be examined and the ascospores germinated if possible. Shortly afterwards (6th May) the following report was received: "A considerable number of the perithecia or winter fruits present on the material sent to Kew were sterile. Others, however, contained normal spores, some of which have germinated. The mycelium shows no sign of life, and judging from the absence of oil globules and stored food material must be dead." A further sample was submitted on the 7th of May, and on the 18th the following report was received: "The majority of the perithecia present on the shoots are much smaller in size than the normal ones and represent the morbid and imperfectly

developed examples that are apt to occur in every crop. Such remain permanently attached to the mycelium. A few normal perithecia containing spores that have germinated were also present. The mycelium has shown no sign of life."

In both of these cases the bushes from which the shoots were taken developed disease in April. A very large number of other bushes in different gardens in Kent developed disease in April also, but in practically every case the diseased shoots had not been entirely removed, and in no case did the mildew appear in that month on any bushes from which the diseased shoots had been removed early in the preceding summer.

Furthermore about the middle of May specimens were sent to the Board by a private grower in Sussex with a request for information as to the nature of the disease. American Gooseberry Mildew was suspected since the berries showed the characteristic white oidium. The writer, however, asserted disease had not been present the year before. On examination, however, old dead mycelium was found on the old wood about an inch or less from the affected berry. This mycelium contained a number of perithecia which presented the appearance of having dehisced *in situ* and the presumption that the infection on the berry is due to the ascospores from these perithecia is at least strong enough to merit consideration.

The two reports received from Kew together with the strong empiric evidence collected by the Board's Inspectors as to the conditions under which early infection occurs appears to me to outweigh the evidence collected by Mr Salmon and published in his papers, and I submit that until much fuller evidence is obtained it would be a great pity to allow growers to suppose that they can ignore the over wintered perithecia on their bushes. All the officers of the Board who have had any experience of this disease are agreed that early tipping is essential for complete success against the disease, but they are I believe all agreed that a partial success may be obtained by late tipping, and that much good may be done by going over the bushes even as late as February or March and removing the affected snags which were overlooked when the bushes were tipped before the leaves fell. The removal of every scrap of disease in the summer or early autumn while the leaves are still on the bushes is a matter of great difficulty. No one suggests that the first tipping should be delayed so long.

Mr Salmon states in the last paragraph of his paper that if tipping is not carried out till the end of October or the beginning of November,

a considerable mass of perithecia must have dropped from the perithecial patches. Many of these perithecia would doubtless lodge in the crevices of the bark or between the bud scales, etc., and assuming that these perithecia were mature ones capable of remaining dormant through the winter, these would on liberating their ascospores infect the adjacent berries. This is a theory to which he says on the whole he inclines. It is of course a very old theory and was, I believe, advanced by the Board in one of their earlier reports, but as I have never heard of any case in which the spores were found in the crevices or scales and as it has been shown that if the visibly affected wood is removed and the bushes transplanted to uninfected soil no disease appears, the theory appears to lack support and it seems to be at least as likely that the reinfection each season is due to the winter fruit in the soil or embedded in the mycelium and due to perithecia dehiscing *in situ*.

A. G. L. ROGERS.

EXOMIAS PELLUCIDUS AS A PLANT PEST.

On May 14th, 1914, an enquiry was received from Charles Townsend, Nurseryman, Fordham, concerning the damage done to a number of plants by the weevil *Exomias* (*Barypeithes*) *pellucidus*. A visit was paid to the Nursery on May 16th and the weevils were found there in enormous numbers.

The plan of the nursery is on the opposite page:

The Thousand heads, Kohl Rabis, Poppies and Nemophylas were all eaten off so that the ground was bare.

The *Collinsia bicolor* and Candytuft were badly damaged and were only saved by a heavy application of lime and soot. The plot containing *Gypsophila elegans* escaped although situated in the middle of the area attacked, so presumably this is not a suitable food for the insect.

Some of the trees were examined and a few of the weevils were found feeding on the leaves of *Acer marginata aurea* and *A. negundo variegata alba*. The potatoes, peas and spruces were free from attack.

Near the attacked area under the spruces large numbers of the insects were found.

There were some rabbit burrows on the nursery and from these it was quite easy to take out a handful of the insects. They had

Boundary Ditch
About 180 yards
Boundary. "Dry Ditch"
Quick Fence
Potatoes
Spruce
Potatoes
Spruce
Prunus Pissardro Trees
Spruce
Acer Negundo Trees
Variegated Acers
Acer Marginata Aurea
Spruce
Thousand head Kale Seed
Destroyed
Fine top Kohl Rabi
Destroyed
Spruce
Acer Maple
Acer Sycamore
Collinsia Bicolor
Partly destroyed
Limes
Laburnum
Sycamore
Collinsia Bicolor
Partly destroyed
Limes
Seedling quicks
Myrobella fence
Spruce
Plane Trees
Walnut Trees
Elms
Limes
Spruce
Thorn Trees
Elms
Limes
Spruce
Poppy (Carnation Flowered)
Destroyed
Poppy (Paeony Flowered)
Destroyed
Gypsophila Elegans
Crop alright
Candytuft
Damaged
Roadway
Limes
Candytuft
Crop undamaged
Limes
Seedling quicks
Limes
Nemophila Insignis
Destroyed
Nemophila Insignis
Destroyed
Ash Trees
Nemophila
Half destroyed
Nemophila
Destroyed
Candytuft
Damaged
Thorns
Candytuft
Crop undamaged
Seedling quicks
Myrobella fence
Entrance to Field

apparently gone here and also under the spruces in order to shelter from the sun. Some of the insects were feeding on a thistle under the spruces.

Leaves of cabbage and rhubarb were put down and on lifting them a few hours afterwards they were found to be entirely covered with the insects on the lower surface, as also were the leaves of the Abele Poplar which had blown from the tree.

The insects usually feed on the lower surface of the leaves at least in the sunlight. A few were found on the upper surface and on the edges. Many young plants were eaten off just above the ground level, *i.e.* through the portion of the stem below the seed leaves. On others (which were not eaten through) were obvious marks caused by the feeding of the beetles. Some of the leaves were damaged by having large holes eaten out of them and in others large pieces were eaten out of the sides of the leaves. They had eaten large holes through some of the cabbage and rhubarb leaves put down to trap them.

The damage was first noticed on May 13th and on May 14th 75 bushels of soot was spread over the attacked area measuring about two acres. This was followed by the application of 30 bushels of lime on May 15th. On May 16th a large number of the beetles were found dead. On June 17th large numbers of dead beetles were present over the attacked area whereas only an occasional live one was found. Cabbage leaves were put down on June 17th and on examining these only three beetles were found. The lime and soot seems to have been very successful in keeping down further attacks of this beetle.

In Fowler's *British Coleoptera* the following is given as the habitat of this beetle: "Sandy places; in moss, etc.; very local and, as a rule, rare, but occasionally in profusion."

It was thought from this that possibly the beetle was introduced by means of peat-moss manure, but on inquiry it was found that no straw manure was used.

I can give no explanation as regards the introduction of this beetle into the nursery which is otherwise comparatively free from insects.

F. R. PETHERBRIDGE,

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SOME FEEDING HABITS OF SLUGS.

The connection of slugs and tapeworms has often been discussed. Some slugs serve as intermediate hosts for certain bird Cestodes (Grassi and Rovelli, 1892) and it has been suggested that they do the same for the Anoplocephaline Cestodes of ruminants and rodents although no convincing evidence has as yet been brought forward (Riehm 1881, Stiles 1893).

An examination into the habits and food of certain slugs made in connection with a research upon lamb tapeworm disease has brought out some interesting facts. The work was done at the Department for Agricultural Research in the University of Birmingham during the summer of 1914.

By the kind permission of their owners, fields were examined on which lambs infected with tapeworm were grazing (the worm commonly found in the Midlands is *Moniezia expansa*, the broad tapeworm of lambs). The fields were in the following localities: Bradley Green and Shurnock near Feckenham, Worcestershire; Oaklands, Allesley near Coventry; Wigmore Grange, Leintwardine, near Ludlow. The golf course at King's Norton near Birmingham was also examined. From the end of April until the end of June the ripe proglottides of this worm were to be found lying about on the fields. At Feckenham and Allesley rabbits were numerous in the same fields and were also infected by a tapeworm (*Cittotaenia pectinata*) and, although I never found the proglottides lying about, the eggs were on the field and could be seen by taking some grass, soaking it in water, and filtering it through cambric. On examining the filtrate the eggs were discovered.

Although *Moniezia* and *Cittotaenia* differ widely they belong to the same group of Taeniids, the Anoplocephalinae, and in all probability their life-histories are somewhat similar.

In these fields were always found two species of slug and only two—*Agriolimax agrestis* and *Arion circumscriptus*, the former very much more common than the latter. In the daytime they are both to be found at the roots of long grass, in holes with dead leaves or even buried in the ground if the season be dry. The habit of burying itself in the ground is very usual with *Arion circumscriptus* and not infrequently it is to be found lying amongst the lambs' faeces.

In the evening the slugs all come out and eat. They also emerge in the daytime after warm rain. It is evident that they are exceedingly

fond of the proglottides of *Moniezia*. I have shut both slugs up in boxes with the lambs' faeces containing proglottides and have always found that they devour the latter with avidity selecting them in preference to the other food. They also eat *Cittotaenia* in the same way.

On June 5th, 1914, twelve *Agriolimax agrestis* were collected and put in a small tin at night with several *Moniezia* proglottides. In the morning all had been eaten. On examining the faeces of the slugs they were found to contain numerous *Moniezia* eggs having apparently passed out with no alteration, some of the hexacanth embryos being still alive. Examination was made of the slugs at various intervals from two days to a month, by teasing up the tissues and by sections. In no case could any trace of a larval Cestode be discovered. Inside the alimentary canal were eggs, but only one was found with the pyriform apparatus free from its outer shell and the embryo itself was unaltered.

It is not only when there is nothing else to eat that the slugs eat the proglottides, for in a specimen of *Agriolimax agrestis* found on the fields at Leintwardine the stomach was full of *Moniezia* eggs.

It is the same with *Arion circumscriptus*. A specimen from Leintwardine also had its stomach full of eggs. One *Arion hortensis* was put in a box with grass and a piece of *Moniezia* consisting of ten proglottides. In half an hour at mid-day it had eaten the whole of this piece. Examination of its faeces showed the eggs unchanged and the embryos alive. The slug was sectionised and examined but no trace of development of the embryo was found. Other specimens gave similar results.

A large mass of *Moniezia* was found in a field at Lower Shuckburgh, Northants, and in it was a small *Arion circumscriptus*. It is evident that the slugs seek out *Moniezia* to eat it.

These slugs also eat *Cittotaenia* and are very fond of eating rabbits' faeces. Both of these species are to be found in the fields devouring the pellets, and their intestines are often full of the brown decaying vegetation from these. Two *Arion circumscriptus* took half an hour to eat one *Cittotaenia*-proglottis each, and four *Agriolimax agrestis* the same length of time.

Eggs of both species of slug were hatched in earthenware pots and the young fed with proglottides of *Moniezia* and *Cittotaenia*. These were examined at intervals but in no case could any development of the embryos be seen.

From these observations there is no evidence to show that *Agriolimax agrestis* and *Arion circumscriptus* act as intermediate hosts for *Moniezia expansa* and *Cittotaenia pectinata*. It was thought that possibly the eggs might undergo some alteration in the intestine which though not apparent might influence their development in other slugs. The slugs' faeces which were full of eggs were offered to other specimens of these slugs but in no case would they eat them.

It is clear that both slugs eat tapeworms on the field. May they not act much more as scavengers than we are in the habit of thinking and do far more good in these fields than we imagine? What is the reason of the abundance of such slugs in these fields? It is quite conceivable that they are there because of the abundance of this Cestode food of which they are so fond.

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NOTE ON THE REMARKABLE RETENTION OF VITALITY BY PROTOZOA FROM OLD STORED SOILS.

Introduction.

In the sample house at the Rothamsted Experimental Station, Harpenden, there is a remarkable collection of soils taken from the experimental plots at various times since the commencement of the famous work by Lawes and Gilbert in 1843. These samples have been stored in bottles the corks of which have been covered with leaden capsules and have thus been insured against the possibility of infection from dust. Many bottles have remained unopened since the day on which they were put up. The exact treatment to which the soils were submitted before being bottled is rather uncertain, but it seems

that they were spread out and allowed to become slightly air-dried so that they could be more easily sieved.

Large bottles capable of holding 200 ozs. were then filled with the soil which had been passed through a sieve having $\frac{1}{4}$ inch meshes. The degree of dryness of the soils varies considerably, some having about 3 per cent. or 5 per cent., others having from 10 to 15 per cent. of water by weight; the samples for any particular year however appear to be of about the same degree of dryness. In most cases the soil was taken from different depths at intervals of nine inches, sampling proceeding in some cases into the deep layers of the sub-soil.

Experiments.

It was my privilege whilst working at the Rothamsted laboratory to examine culturally soil from a few of these bottles for the presence of protozoa and only samples from the top nine inches of a plot were tested. In some preliminary experiments in 1912 it was found that Broadbalk soil bottled in 1846 revealed no protozoa in culture, but that Barnfield soil bottled in 1870 yielded amoebae and flagellates, and Agdell soil bottled in 1874 yielded amoebae and flagellates, and the ciliates *Colpoda steinii* and *Colpoda cucullus*, in hay-infusion cultures.

These results were very interesting as showing that the protozoa had retained their vitality probably in the encysted condition for a period of 42 years in the case of the Barnfield soil and 38 years in the Agdell soil.

As there were other bottles containing soil put up between 1846 and 1870, I decided to make cultures of some of these with a view to finding out the oldest soil from which protozoa could be obtained and the different species of protozoa which had survived.

Dr Russell, director of the laboratory, very kindly granted me permission to take small quantities of the soil from those bottles which I desired to test and I take this opportunity of thanking him for allowing me to make use of these valuable soils.

The following soils were tested for the presence of protozoa; Broadbalk 1856, Broadbalk 1865, Geescroft 1865, Agdell 1867, Hoosfield 1868, and Barnfield 1870. From all the cultures except those of Broadbalk 1856 protozoa were obtained. The cultures were made in small glass dishes under the usual bacteriological precautions of sterile media and vessels, etc., so that there can be no doubt that the organisms encountered really came from the soil and not from air-borne dust particles by chance infection.

As a culture medium, saline egg-albumen consisting of 5 per cent. NaCl solution 100 c.c., white of new-laid egg 15 c.c. was used.

Film preparations were made by floating cover-slips on the surface or by placing them at the bottom of the cultures. The films thus obtained were usually fixed in Maier's solution and stained with iron-haematoxylin.

It is not the purpose of this paper to go into details concerning the different species of protozoa found, but especially to put on record the remarkable fact of the survival of protozoa for practically 50 years under conditions precluding the possibility of trophic existence.

The following protozoa have been identified. The list does not include all the forms encountered, for there are a few which I have not been able to classify satisfactorily yet.

Amoebae belonging to the *limax* group were obtained from all the soils which yielded protozoa. I have made observations on the mode of nuclear division in three of these with the result that all three appear to be new species. One of them seems to be very closely related to *Amoeba glebae*[1] Dobell. Flagellates: *Monas termo*, *Cercomonas crassicauda*, *Cercomonas longicauda*, *Bodo* (*Prowazekia*) *saltans*, *Bodo ovatus*? and *Tetramitus spiralis*, nov. spec.

In addition to the above I have obtained a rather remarkable organism which undoubtedly belongs to the genus *Spironema* Klebs[2]. Klebs obtained his examples from ditch-water on only two or three occasions and considered that they showed affinities with ciliates and flagellates, forming perhaps a sort of connecting link between these two groups. He did not, however, find out anything about the nucleus.

I have succeeded in making out the nucleus which, though peculiar, exhibits flagellate rather than ciliate affinities.

Historical.

It may be of interest, in view of the great length of time which the resting cysts of these protozoa have retained their vitality, to state briefly the previous records of similar phenomena.

According to Butschli[3], Meunier (1865) saw *Colpoda* emerge from cysts dried for fourteen months. Balbiani (1881) kept a slide with

[1] "Cytological Studies on three species of Amoeba, etc." *Archiv f. Protisten.* Bd. 34 (1914), p. 139.

[2] *Flagellatenstudien I. Zeitschr. f. wiss. Zool.* LV (1892), p. 350.

[3] Bronn's *Thierreichs* I, Abth. III, p. 1663.

Colpoda cysts on it for seven years and resuscitated the organism each year by moistening the slide; they afterwards encysted. I think that this can scarcely be considered as a case of retained vitality for seven years, for the *Colpoda* obtained a new lease of life each year when the slide was moistened. Nussbaum found cysts of *Gastrostyla vorax* capable of living after two years and Maupas saw *Gastrostyla steinii* cyst after twenty-two months drying in a watch-glass.

These records refer to ciliates only and the longest period of retained vitality, excluding Balbiani's results with *Colpoda* for reasons given above, is two years. I have shown above that two species of *Colpoda* have retained their vitality for 38 years.

I cannot find any reference to early work on these lines in the case of flagellates and amoebae. Quite recently however Noc[1] has published a short paper dealing with latent life in protozoa. Some tubes containing a little water and various protozoa were hermetically sealed in 1908 and recently opened. There was no trace of anything but encysted amoebae, some of which revived after ten days or more. This proves survival for six years. A minute flagellate *Oikomonas termo* was obtained from some rough Tonkin paper after desiccation for five years.

The retention of vitality for a period of forty-nine years which I have recorded above shows that protozoa can survive in an encysted condition for a much longer time than was known from previous records.

I deal with the significance of these results in relation to the hypothesis of protozoa acting as a limiting factor on soil bacteria in another paper which I hope to publish very soon. A further paper embodying the cytological work on the organisms obtained from these old soils with descriptions of new species is also being prepared.

In conclusion I desire to express my thanks to Prof. F. W. Gamble, director of this laboratory, who suggested, about three years ago, the desirability of examining samples of old stored soils for the presence of protozoa.

Postscript.

Immediately after submitting the foregoing for publication I obtained access to Noc's paper[2], only the abstract of which I had been

[1] Noc, F., *C. R. Soc. Biol. Paris*, LXXVI (1914), pp. 166–8. *Abst. Jour. Roy. Mic. Soc.* 1914, pt. 3, p. 267.

[2] "Sur la durée de conservation de Protozoaires à l'état humide ou desséché" (*C. R. Soc. Biol. Paris*, LXXVI (1914), p. 166).

able to see earlier. In it he speaks of the results obtained by Certes who found that various infusoria, flagellates, and amoebae could be revived after five or six years only from the sediments on which he worked, whilst only *Colpoda* remained capable of revival after thirteen years of storage.

A reference is also given to a paper by Fauré-Frémiet[1] on a ciliate *Mycterothrix*. On looking this up I find that it records that Balbiani working with desiccated material containing cysts of *Mycterothrix* was able to revive the organisms by moistening after keeping the material dry for four years.

T. GOODEY, M.Sc., *Protozoologist, Research Laboratory for Agricultural Zoology, Birmingham University.*

NOTES ON A SCALE INSECT ATTACKING CACAO IN UGANDA.

In 1909 a scale insect attacking cacao appeared in the Botanic Gardens. Specimens of this new pest were submitted for identification to Prof. Newstead, who described it as a new species, *Stictococcus dimorphus* Newst.[2].

The other food plants on which it has been collected by the writer are mulberry, *Markhamia platycalyx*, ornamental Hibiscus, *Anona muricata*, *Croton tiglium*, guava and *Cajanus indicus*. With the exception of *M. platycalyx*, all of these plants have been introduced, which, together with the fact that this Coccid has been found in the depths of a forest of something like 180 square miles on *M. platycalyx*, is conclusive evidence that it is indigenous and that it spread from that plant to the others.

From my observations cacao appears to be the favourite food plant. When the varieties of cacao, *foresteiro* and *creolle*, are grown side by side, the infestation on the former is invariably the most serious. The infestation on cacao is always restricted to the pods and stems of the pods, never having been found on the foliage or branches. (Fig. 1.)

[1] "Le *Mycterothrix tuamotuensis* (*Trichorhynchus tuamotuensis*) Balbiani." (*Arch. f. Protist.* xx, p. 223, 1910.)

[2] Newstead, *Bulletin Entomological Research*, vol. 1, p. 63, f. 2 (1910); Green, *l.c.*, p. 201 (1910).

Treatment. This is not readily killed by insecticides at the usual strengths; but, fortunately, on account of its always being located on the pods, insecticides can be used at greater strengths than they could be applied to the foliage in this country, where the trees are never dormant and where for some reason, probably altitude, oils applied at the usual strengths are most apt to "burn" the foliage.

I have experimented with a large number of contact poisons with the result that I favour the use of whale oil soap and soft soap-kerosene emulsion. The results of some of the experiments are tabulated below.

Spraying Experiments against the Cacao Scale, St. dimorphus Newst.

Experiment number	Treatment	Number of pods treated	First examination			Second examination			Third examination		
			Number of scales examined	Number of scales dead	Percentage of dead scales	Number of scales examined	Number of scales dead	Percentage of dead scales	Number of scales examined	Number of scales dead	Percentage of dead scales
1	Whale oil soap	8	300	288	96·0	300	281	93·6	300	285	95·0
2	Kerosene emulsion	8	300	226	75·3	300	214	71·3	300	210	70·0
3	Carbolic acid emulsion ..	10	500	242	44·4	500	251	50·2	500	205	41·0
4	Resin-soda wash	8	300	83	27·7	300	99	33·0	300	78	26·0
5	Lime-sulphur wash	12	500	491	98·2	500	436	87·2	500	401	80·2
6	Kerosene-lysol emulsion ..	12	500	268	53·6	500	261	52·5	500	274	54·8
7	Soft soap-kerosene wash ..	12	500	482	96·4	500	469	93·8	500	456	91·2
8	Check	—	300	23	7·7	300	17	5·7	300	28	9·3

Experiment 1 was sprayed with whale oil soap, 1 lb. to 4 gallons of water.

Experiment 2. The formula of the stock solution of kerosene emulsion was:

Kerosene	2 gals.
Soap, hard	½ lb.
Water, hot	1 gal.

The stock solution was diluted to a 20 per cent. spray, *i.e.* 1 gallon of the stock solution was diluted with 2⅓ gallons of water.

Experiment 3. The stock solution of carbolic acid emulsion was made according to the formula:

Soap, hard	1 lb.
Water	1 gal.
Carbolic acid, crude	1 pt.

One part of this solution was diluted with 30 parts of water.

Photo by T. D. Maitland

Fig. 1. A typical infestation of a pod of *Cacao theobromae* var. *forestiero*, with *Stictococcus dimorphus* Newst.

Experiment 4. The formula of the resin-soda wash was:

Soda, caustic	3 lbs.
Resin	10 lbs.
Fish oil	¾ lb.
Water	25 gals.

Experiment 5. The stock solution of lime-sulphur wash was made according to the formula:

Lime, unslaked	20 lbs.
Sulphur, flowers of	15 lbs.
Water	50 gals.

and this was diluted to 85 gallons.

Experiment 6. Kerosene-lysol emulsion was made by emulsifying:

Lysol	3 ozs.
Kerosene	9 ozs.
Water	4 gals.

Experiment 7. The soft soap-kerosene wash was made by boiling together 8 lbs. of soft soap and 5 gallons of kerosene. On cooling this becomes a jelly, 10 lbs. of which was added to 30 gallons of water for use.

Experiment 8. For the purpose of comparison eight untreated pods were examined.

Natural enemies. I have frequently bred the Noctuid, *Eublemma costimacula* Saalm., of the subfamily *Erastriinae*, from this scale insect. During the examination of the pods treated with the above-mentioned sprays for dead insects several larvae of this moth parasite were found.

At a distance I have observed the bird, *Melanopteryx nigerrima*, picking at a cacao pod infested with this scale insect, but I could not be certain whether it was feeding on the scale insect or on the ants which accompany the scale insect.

The other local representatives of the genus *Stictococcus* are the species recently discovered by the writer, *St. formicarius* Newst., and *St. gowdeyi* Newst.[1] The former attacks a species of *Ficus*, and the latter *Harrogania madagascarensis* and coffee.

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[1] Newstead, *Bulletin of Entomological Research*, vol. IV, p. 70, f. 4 (1913).

REVIEW.

STEBBING, E. P. *Indian Forest Insects of Economic Importance. Coleoptera.* London, Eyre and Spottiswoode, Ltd., 1914, pp. xvi + 648, Plates I–LXIII and 401 text-figures.

The author of this work was formerly a divisional forest officer in India who all through his career has devoted much of his energies to entomology. It redounds to his credit that he urged the importance of forest entomology in the eyes of the government of India, and in this way did much towards securing the creation of an official post to deal with the subject. In the year 1900 the office of Forest Entomologist was established for a period of two years, and Mr Stebbing appointed the first incumbent thereof. In 1904 the post was resanctioned, while in 1906 it was merged into the new appointment of Forest Zoologist. Mr Stebbing was also the first official Forest Zoologist to the government of India. During his tenure of these appointments he has produced a large amount of matter dealing with forest insects. Published for the most part in sources not easily available to entomologists, many of Mr Stebbing's writings are little known outside India, and have seldom had the advantage of scientific criticism. Observers in India are so few and far between that little has yet been done towards confirming or extending Mr Stebbing's work. On his departure from India he took upon himself the no light task of compiling the book before us. Without hesitation it may be said that it is the best piece of work Mr Stebbing has yet produced. Being free from almost all the errors and faults which marred his previous text-book of Indian Forest Zoology, we congratulate him on having written a very readable and excellently arranged book. Notwithstanding the title on its outside cover, the volume is limited to forest Coleoptera, and in confining his remarks to this single order of insects Mr Stebbing has exercised a wise decision. To have included the remaining orders would have savoured of indiscretion in view of the scanty state of our knowledge of Indian forest insects.

In his Preface Mr Stebbing has been generous to all who have helped him in any way. From Inspectors-General of Forests and the Lieut.-Governor of a Province down to the toiling camp clerk, acknowledgments are freely made. We do not ever remember having seen quite such an array of names in any book before.

Chapters I–IV are devoted to general remarks on the distribution of insects in the Indian forests, on injurious and beneficial species, remedial and preventive measures and other problems.

Chapter V consists of a brief introduction to the Coleoptera. We think, however, that the all-important section dealing with Coleopterous larvae might have been greatly extended to advantage. References to the works of Schiodte, Chapuis and Candeze, Perris, Rupertsberger and others would have acquainted the reader with the sources to which he must eventually turn for information concerning life-histories. The greater part of the book is occupied with an account of the forest Coleoptera arranged in systematic order and extending to over 560 pages. All the principal species known to the author are figured, and a brief description of each is given. Wherever information is available remarks on the injury they commit are made, which are usually supplemented by really excellent photographic plates. Here and there short descriptions of the larvae and pupae of various species are to be found. These descriptions, however, in most cases are too brief and vague to enable one to determine a particular larva with any degree of certainty. To merely describe, for instance, the pupa of *Cyrtotrachelus longipes* as being white and of the ordinary weevil shape, really does not help very much. Neither can we recognise the larva of *Sphenoptera cupriventris* when it is simply stated to be yellowish white with stout black mandibles, and the prothoracic segment broader than any of the segments behind it. In fact most Buprestid larvae may be said to agree with that description. One of the best life-histories in the whole book is that of the Longicorn *Hoplocerambyx spinicornis*, concerning which a good deal of useful information is brought to light by Mr Stebbing. It is not, however, absent from the Sal forests of the United Provinces as he believes. Perhaps the most interesting of the insects found by Mr Stebbing are the predaceous beetles of the genus *Niponius*. Although usually placed in the family Histeridae, there is something to be said for elevating them into a family of their own. So far, we know nothing of the larva of *Niponius* beyond what Mr Stebbing can tell us. If he can be constrained to publish an illustrated account thereof, it will not

fail to be of great interest to the Coleopterist as well as being of economic value.

The Scolytidae (Ipidae) are treated the fullest of any of the families, some 150 pages being devoted to them. The author has brought to light many species, some of them very obscure and easily overlooked. It is, however, hard to recognise some of Mr Stebbing's species from his descriptions. The writer of this review has devoted many hours over *Tomicus* (*Ips.*) *longifolia* and *T. ribbentropi* without being able to separate the one from the other. The same may be said with regard to certain of his *Polygraphus* and other species. In view of their great economic importance, the Indian Scolytidae are badly in need of revision. The government of India would do well to issue a monograph of all known Indian species with detailed figures, exhibiting beyond any possibility of doubt the diagnostic characters in each case. The monographs of Dr Hopkins in America would serve as an admirable model to emulate. In the Scolytidae closely allied species often exhibit dissimilar habits, and it becomes a matter of the greatest importance to name any particular species with certainty. In no other group of forest insects, that we are acquainted with, does the work of forest protection depend so much upon accurate specific determinations as in the Scolytidae.

We would impress upon the author that it is neither necessary nor desirable to describe new species in a general text-book of this description. We find that Mr Stebbing appears to have done so in more than a dozen instances. Furthermore to designate already described species as "sp. nov." is contrary to all recognised procedure. The expression "sp. nov." in such cases is highly misleading; for instance on p. 621 the reader would at first sight conclude that "*Platypus suffodiens* Sampson, sp. nov." is a new species described immediately below by Sampson. On the contrary the reference is given to the *Ann. Mag. Nat. Hist.* for 1913 where the original description is to be found.

Notwithstanding the points over which we disagree with the author, we think that the book will prove a distinct stimulus to Indian forest entomology. Most of the divisional forest officers, scattered through the length and breadth of the Indian Empire, are familiar with one or other form of destructive insect life in the lands under their charge. With the aid of this book perhaps some of them may be tempted to make a more serious study of the subject, or by collecting specimens and information help others to extend the boundaries of our knowledge of a wide and little explored field.

In conclusion we may add that the general "get up" of the book is admirable, and reflects the greatest credit on all concerned with its production. The majority of the plates are of a high standard of excellence and the same may be said of many of the text-figures. Exception, however, must be taken to figures 30 *d*, 65, 96, 107, 125, 138, 150, 154, 157, 159, 200, 291, 305, 324, and 385—also to Plate XV, figs. *a* and *a'*, and Plate XXXVI, fig. 2, all of which bear but little resemblance to the objects they are intended to represent. The paper and type utilised leave nothing to be desired, and we have noticed an almost complete absence of misprints.

A. D. I.

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